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Technical Report

Neurocognitive & Physical Abilities Assessments Twelve Years After the Chernobyl Nuclear Accident

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13. ABSTRACT *(Maximum 200 words)*
In an effort to assess the effects of exposure to ionizing radiation on neuropsychological and physical abilities, a longitudinal study in and near Chernobyl, Ukraine was conducted. In this report are findings from 1995 to 1998. Participants were volunteers who resided in Ukraine during and since the Chernobyl Nuclear Power Plant accident. A translated subset of the Automated Neuropsychological Assessment Metrics battery and the Gamache Physical Abilities Battery were administered to a control and three experimental groups. Controls were healthy volunteers who resided well outside of the exposed area. Eliminators were decontamination and reconstruction workers with known levels of exposure. Forestry and Agricultural workers resided and worked in contaminated areas. Analyses of 1995 – 1998 4-year averaged results indicated the Eliminators were significantly impaired on all measures of neurocognitive

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and physical performance as compared to Controls. Forestry and Agricultural workers were impaired on subsets of the neurocognitive and physical batteries. Significant correlations between levels of radiation dosage and 4-year averaged physical and cognitive performance were observed on 21 of 24 tasks for the combined exposure groups. The results appear to reflect the existence of clinically meaningful neurotoxic effects of both acute and chronic exposure to radionuclides.

PREFACE

This document represents the Final Report of a four year effort sponsored by the Defense Threat Reduction Agency (DTRA). This report provides the Tables and Figures to substantiate the effects of low-dosage radiation (less than 70 rads) on a Ukrainian population exposed as a result of the Chernobyl disaster.

The success of this study was dependent on the active participation of a group of subject matter experts from military and civilian services on an international basis. Our first line acknowledgment and sincere appreciation is extended to our sponsor, the United States Defense Threat Reduction Agency (DTRA). Further, special thanks goes to Robert A. Kehlet, our Program Manager at DTRA. He has been our champion in this project, and successes to date are due to his dedicated scientific and program guidance.

Development of the TWB/ANAM, which has served as the neuropsychological test instrument in this project, was sponsored by the U.S. Army Office of Military Performance Assessment Technology, Walter Reed Army Institute of Research, Washington, DC, Dr. F.W. Hegge, Program Director. The TWB/ANAM system was constructed at the Naval Computer & Telecommunications Station, NAS, Pensacola, FL, K. P. Winter, Principal Investigator. Authors of the ANAMUKR Battery were D. Reeves, G. Gamache, A. Chervinsky, & P. Bidiouk. Finally, the authors would like to express a special note of appreciation for the exceptional volunteer technical assistance provided by Dr. J. Wood, Krug Life Sciences during the English to Russian/Ukrainian portion of this project. Her knowledge and experience with the NASA-MIR projects proved invaluable in helping us to not “re-invent” the wheel and launch our project “on-schedule.”

On-site Supervisors in the Ukraine were: Damian V. Kolisnyk, who supervised all aspects of testing the control group, Nikolay N. Kaletnik, who supervised all aspects of testing the forestry workers, and Victor G. Bondarenko, who supervised all aspects of testing the eliminators. Dr. Peter I. Bidiouk was the on-site project scientist and over-site supervisor for all aspects of the selection of test sites and the selection of participants, as well as being the on-site project administrator in Ukraine (see Appendix A).

Finally, the authors would like to express sincere appreciation to Dr. A. J. Glasner, National Cognitive Recovery Foundation Editorial Board Member, who has been instrumental in production of this report and helping us remain “on-track” and in adherence with NCRF/APA guidelines.

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement.

MULTIPLY →	BY →	TO GET
TO GET ←	BY ←	DIVIDE

angstrom	1.000 000 X E -10	meters
atmosphere (normal)	1.013 25 X E +2	kilo pascal (kPa)
bar	1.000 000 X E +2	kilo pascal (kPa)
barn	1.000 000 X E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 X E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical/cm^2)	4.184 000 X E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 X E +1	*giga becquerel (GBq)
degree (angle)	1.745 329 X E -2	radian (rad)
degree Fahrenheit	$t_k = (t°f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 X E -19	joule (J)
erg	1.000 000 X E -7	joule (J)
erg/second	1.000 000 X E -7	watt (W)
foot	3.048 000 X E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (u.s. liquid)	3.785 412 X E -3	meter^3 (m^3)
inch	2.540 000 X E -2	meter (m)
jerk	1.000 000 X E +9	joule (J)
joule/kilogram (j/kg) radiation dose absorbed	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 X E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 X E +3	kilo pascal (kPa)
ktap	1.000 000 X E +2	newton-second/ m^2 (N-s/m^2)
micron	1.000 000 X E -6	meter (m)
mil	2.540 000 X E -5	meter (m)
mile (international)	1.609 344 X E +3	meter (m)
ounce	2.834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 X E -1	newton-meter (N·m)
pound-force/inch	1.751 268 X E +2	newton-meter (N/m)
pound-force/foot^2	4.788 026 X E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 X E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 X E -2	kilogram-meter^2 (kg· m^2)
pound-mass/foot^3	1.601 846 X E +1	kilogram-meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 X E -2	**Gray (Gy)
roentgen	2.579 760 X E -4	coulomb/kilogram (C/kg)
shake	1.000 000 X E -8	seconds (s)
slug	1.459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 X E -1	kilo pascal (kPa)

- The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
  **The Gray (Gy) is the SI unit of absorbed radiation.

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SECTION 1
INTRODUCTION

The nuclear reactor accident at Chernobyl in 1986 resulted in geoecophysical damage and polluted farmlands and forests with radioactive contamination in im
mediate and outlying areas. It has been estimated that 72% of the land mass of Ukraine is contaminated, and will be so for thousands of years (Yakovlev, 1992). By 1988, the Ukrainian registry contained names of 347,619 civilians who had experienced medical symptoms that are frequently associated with exposure to the ionizing radiation fallout. In addition, 36,000 military personnel (Yakovlev, 1992) were listed as adversely affected. By 1992, over 1.5 million individuals were on government registries as having suffered medical problems associated with radiation exposures. This group included 350,225 children and 180,144 persons assigned to "clean-up" duties at or very near the accident site (Awramenko, 1992). By 1993, about 7,000 people had died from apparent radiation-related illnesses, including heart, vascular, respiratory, and digestive diseases. One area of investigation that has been neglected during the aftermath of the Chernobyl accident has been the possible long term and subtle effects on neuropsychological functions.

According to Chernousenko (1991) and Gittus et al. (1988), construction started on the Chernobyl Nuclear Power Plant (CNPP) in March, 1970. Plans called for construction of six High Power Channel Reactors, each having the capability to generate 1,000 megawatts of electricity. These are single-loop reactors, which means that steam travels directly to the turbine for electric generation. On September 28, 1977, the first of four reactors for CNPP became operational. Engineers working at the site warned of substantial problems because the reactor was unstable and emitting small doses of radioactivity. Despite these problems, more reactors were built, all operational until Saturday, April 26, 1986, when at 1:23 AM the fourth reactor exploded. The blast ripped off the roof and radioactive waste in the form of plutonium, cesium, and uranium dioxide were released (see Figure B-1 in Appendix B).

At the reactor site, a 30-kilometer exclusion zone was established by the government to keep out non-scientific personnel. Cleanup and containment crews were dispatched to the scene where approximately 660,000 volunteers and soldiers were employed. Only the Russian radiation monitors were outfitted for the task at hand (Figure B-2). The rest were "eliminators" composed of military units (infantry, helicopter crews, and engineer units), Ukrainian police, tractor and truck drivers from all Ukrainian provinces, medical doctors and nurses, scientists and engineers from Ukraine, Belarus, and Russia, and farm laborers (men and women) from Ukraine and Russia. The Ukrainian volunteers were approximately 396,515, while those living in Belarus and Russia comprised approximately 264,343. These cleanup crews were dressed only in surgical masks and lead aprons (Chernousenko, 1991). In neighboring Pripyat the population of 55,000 was not evacuated until 36 hours post-accident. Meanwhile in Kiev, government officials detected large doses of radiation; however, they chose not to cancel a planned May Day parade.

Several years later, the accident continued to bring suffering to millions of people in the Ukraine, Belarus, and Russia. According to Baranov and Guskova (1988), and Laupa and Anno (1989), thirty-one workers at Chernobyl Nuclear Power Plant died a little over three months post-accident as a result of acute radiation sickness.

Baryahtar (1991) reported that as many as 7,000 have died since then of radiation-related illnesses, and The International Chernobyl Project claimed that the scientific community lacked research and information on the medical consequences of radioactive pollution. Read (1993) stated that the number of fatalities ranged from thirty-one to "a projection that Chernobyl will ultimately claim more victims than did World War II."

According to the newspaper Vestnik Chernobylia, Ukraine produces 54.4 million kilowatts-year of energy annually. Over 62% is generated from coal or oil burning plants, 8.3% from hydroelectric plants, 23.5% from other nuclear power stations, and 5.5% from the two operating reactors at the Chernobyl Nuclear Power Plant. In the winter of 1992-1993, nuclear power plants accounted for 40% of all electric power generated. In 1990, 5.8% of this power was generated by Chernobyl; in 1991 the rate dropped to 5.2% while in 1992 the rate was only 2.2%.

Two reactors are still operational at Chernobyl (Figure B-8). The third reactor was destroyed in a fire in October, 1991. Each reactor is programmed for 30 years of service; however, the two remaining reactors were scheduled to be deactivated in 1993. Decommissioning will cause substantial problems because the four reactors have generated over 244 million kilowatts-year of energy, including 94 million kilowatts-year since the accident. The two remaining reactors have the capability of generating 10.3 million kilowatts-year of electrical energy at a cost of $515 million dollars. Utilizing them would save 2.6 million tons of oil or 6.1 million tons of coal, purchases the Ukrainians cannot afford. In October, 1993, the law which would have closed Chernobyl by the end of 1993 was repealed.

For the year 1989, the absorbed dose for people at Chernobyl was 1.3 rads compared with a lifetime dose of 35 rads. In 1992, the absorbed dose was only .97 rads. The amounts released into the atmosphere by the cracking sarcophagus comprise only 20% of the rate of the fully functional reactor.

Decommissioning will involve four steps. First, the reactors are shutdown with a one-year cooling period. In step two, the nuclear fuel is removed and kept in water for one to two years before placing it in special storage. In stage three, Chernobyl will be temporary closed for a period of 20 to 30 years to allow any radionuclides present in the facility to decay. Finally, in stage four, Chernobyl will be dismantled.

When Chernobyl was fully operational, a total of 50,000 persons worked at four reactors. By 1987-1988, 90% of these workers had been replaced. Of the replaced workers, more than 90% were under the age of 45 and 60% graduated from a university or technical colleges. Today, the 25,000 present staff lived about 50 kilometers from Chernobyl in the town of Slavutych, which was constructed in 1986 after the town of Prypiat was evacuated.

Debate over the future of Chernobyl is still going on in the Ukrainian Supreme Soviet. On one side of the debate are those who believe the economy of Ukraine will not improve by decommissioning. They point out the replacement cost of alternative methods of generating
electricity. They also point out the Dnieper basin has seven other reactors with the same design as Chernobyl, and another similar reactor will soon be operational near Kursk. They argue that Chernobyl has a highly trained staff which will go elsewhere if the reactors are decommissioned, and each year savings from nuclear power can be turned to clean-up efforts and treating those still suffering from the accident.

Finally, they argue that other third-world governments are not decommissioning Russian-made RBMK reactors; in fact, Russia is planning to double energy production by nuclear power by the year 2010, although they will not rely on the RBMK reactor.

According to Yakovlev (1991), the Chernobyl incident resulted in waste emission of approximately 50-80 million Curies (Ci), including over a million Ci of Cs^{137}, 200,000 Ci of Sr^{90} and between 3,500 and 5,500 Ci of $Pu^{239/240}$ into the environment.

His research states that as of January 1, 1992, forty three thousand square kilometers, or 15% of the Ukraine, was contaminated by Cs^{137}, with doses greater than one curie per square kilometer. Over 72% of Ukraine is contaminated above background radiation. This area has 3,200 towns and villages and a population, excluding Kiev, of over 4,000,000 people. Migratory birds and animals carry radiation-related diseases along their routes, increasing the contaminated area. Table 1-1 (Sobodovych et al, 1992) shows contamination from Chernobyl as compared with that resulting from nuclear weapons tests. While Chernobyl nuclear contamination is low compared with Russian nuclear weapons tests, the scientific community cannot afford to forget the fact that Chernobyl is adjacent to a heavily populated area.

Table 1-1. Comparison of radionuclide content released into the environment as a result of nuclear weapons tests with levels resulting from the Chernobyl accident.

Type of radio-nuclide	Half-life in years	Nuclear weapons test (million Ci)	Total in reactor (million Ci)	Chernobyl outburst %	Chernobyl outburst (million Ci)	% of NWT
Sr^{90}	28.60	57.5	6.00	6.0	0.30	0.50
Cs^{137}	30.17	87.0	7.02	30.0	2.10	2.40
Pu^{238}	87.74	0.0055	0.0254	9.0	0.00076	13.80
Pu^{239}	24118.00	0.96	0.0256	9.0	0.00077	0.20
Pu^{240}	6570.00	0.50	0.040	9.0	0.0012	0.20
Pu^{241}	1435.00	23.00	4.97	9.0	0.15	0.70
Pu^{242}	$.763 \times 10^5$	0.00045	0.000056	9.0	0.000002	0.40

It should be noted that 50-80 *million* curies of radiation were released into the environment from the Chernobyl accident, as compared to only 14-20 from the Three Mile Island incident.

During the accident, reactor cooling water was flushed into the Prypiat River, a tributary of the Dnieper, rather than allowing more radioactive steam to escape into the atmosphere (Chernousenko, 1991). The result of this action, and the break in the sewage system that serviced the Chernobyl cleanup effort, are the principle causes of radionuclide pollution in the Dnieper and Prypiat rivers, as well as their water reservoirs which serve to irrigate the region. Thus the contamination is spread. At present, the vertical migration of radionuclides approaches a depth of one meter from the surface.

According to Professor V. Kopeikin (1993), water near the burial place of Chernobyl debris is about 4 meters underground. Ten wells with filters installed were constructed on-site to monitor ground water contamination. These wells are monitored daily and were placed every four meters, with depths ranging from 8-9 meters.

The damaged reactor is covered by a sarcophagus composed of 220,000 m^3 of concrete and 15,000 m^3 of steel, around which there are 5 to 6 meters of "clean topsoil" (Yakovlev, 1991).
However, the sarcophagus has approximately 700 square meters of heat cracks caused by the damaged reactor core underground. The cracks cause venting of radioactive materials from fragments of the reactor core and the graphite bed underneath it. About 75% of the residual nuclear fuel is composed of clinker (135 tons) and nuclear dust (10 tons). The maximum temperature at the surface is 60 degrees centigrade, while the temperature underground approaches 200 degrees centigrade.
On the surface radioactive contamination is about 3,000 roentgen per hour. In 1990-1991 the outburst from radioactive dust was 1,000 times less than that of a working reactor. However, with time and clinker decomposition, the amount of nuclear dust will increase. On May 30-31, 1990, Chernobyl was struck by an earthquake measuring 4.0 on the Richter scale. No damage to the sarcophagus was reported. In 1992 the Ukrainian government opened bidding on a replacement sarcophagus. In June, 1993, the lowest bidder, a French company, began studying the problem. During 1987-1990, 270,000 rubles were spent to increase safety of all reactors in the Ukraine.

According to Woytsehowich (1991), as shown in Table 1-2, between 1986-1990 the amount of Cs^{137} in the Kiev water reservoir increased more than 17 times. In the Kremenchug reservoir, approximately 170 miles south of Kiev, the pollution has doubled; this signifies a spreading of radionuclides along the Dnieper basin.

Table 1-2. Volume of Cs^{137} in the Dnieper reservoirs, measured in curies.

Reservoir	1986	1987	1988	1989	1990
Kiev	413	850	--	1000	7200
Kanev	60	--	--	570	2200
Kremenchug	150-200	--	218	294	294

The maximum values of specific activity of radionuclides as well as heavy metals are in riverbeds and shallow bays, while the minimum values are in the floodlands and irrigated fields. From CNPP, along the Prypiat and Dnieper rivers, down to Kiev Reservoir, three contamination zones have been established (Woytsehowich, 1991) for those areas affected by Cs^{137}. The Migration Zone lies along the Prypiat river between CNPP and its entrance into the Dnieper. The Accumulation Zone is from the mouth to 15 kilometers upstream from the reservoir dam. The Wash Away Zone is from the point 15 kilometers from the dam to the dam itself.

Table 1-3 (Sobodovych et al., 1992) shows soil contamination in Kiev and its suburbs to be .015 to 5.31 Ci/Km^2 for Cs^{137}, .02 to .80 Ci/km^2 for Ce^{144}, and .03 to 1.57 Ci/km^2 for Ru^{106}. Not shown in Table 1-3 is the contamination by Sr^{90}, which is 50-750 Ci/Km^2. The concentration of plutonium was reported by two sources. Source 1 (Ukrainian) shows the level of contamination to be 5 to 10 Ci/km^2, while Source 2 (Russian) shows the level of contamination to be much lower--0.1 to 2.7 Ci/km^2. The authors were given no explanation for these disparities.

Table 1 –3. Distribution of radionuclides in Kiev and suburbs.

Radionuclide	Activity (Ci/kg)	Density of contamination (Ci/km^2)
Cs^{137}	2.6 x 10^{-10}/7.94 x 10^{-8}	0.015-5.31
Ce^{144}	3.06 x 10^{-10}/1.12 x 10^{-8}	0.02-0.80
Ru^{106}	4.31 x 10^{-10}/2.19 x 10^{-8}	0.03-1.57

Note: (1) Maximum Contamination Levels in Kiev
1880 mCi/km^2 (Kudry, Pechersk)
4524 mCi/km^2 (Montazbnikov, Sovley)
1182 mCi/km^2 (Davydova, Rusanovka)
1367 mCi/km^2 (Kybalchiucha, Voskresenka)
1105 mCi/km^2 (Kosmomantov, Otradny)
(2) Pu Contamination:
Source 1: 5 - 10 Ci/km^2
Source 2: 0.1 - 2.7 Ci/km^2

The city of Kiev comprises 340 km^2; however, only 7% is contaminated, mostly with Cs^{137}. As shown in Tables 1-4 and 1-5 (Sobodovych et al., 1992), in the largest area in the Kiev region which includes the city plus surrounding countryside, fifty percent of the total landmass has received greater than 40 Ci/km^2 of contaminated radiation. This exceeds the recognized standard for lifetime exposure rate of 40 Ci/km^2; however, the city itself is quite habitable.

Dr. Kaletnik, Head of the Scientific and Technical Office for the Ministry of Forest, was questioned why the Kiev region, rather than the city itself, was so highly contaminated. He explained that this phenomenon was due to excessive forest fires in the area, and that rising smoke and soot which blankets an area after rainfall would increase already high levels of contamination.

Table 1-4. Contamination by Cs^{137}.

Concentration Intervals (Ci/Km^2)	0.5-1.0	1.0-5.0	5.0-15.0	15.0-40.0	< 40.0	Sum
Region	**Contamination of Cs^{137} measured in square kilometers**					
Polissya	1837.5	2000.0	187.5	-	-	4025.0
Korosten'	2162.5	92.5	2625.0	1125.0	-	6005.0
Upper-Prypiat	950.0	1900.0	187.5	-	-	3037.5
Kiev	5100.0	3575.0	4750.0	4500.0	18000.0	35925.0
Carpathian	62.5	-	-	-	-	62.5
Chernigov	687.5	75.0	-	-	-	762.5
Ternopol	2125.0	1000.0	-	-	-	3125.0
Podilsk	2500.0	4075.0	975.0	-	-	6975.0
Lviv	37.5	-	-	-	-	37.5
Mukachev	150.0	75.0	-	-	-	225.0
Pridneprov	437.5	325.0	-	-	-	762.5
Avratynsk	2412.5	3175.0	150.0	-	-	5737.5
Samarskij	337.5	37.5	-	-	-	375.0
Donetsk	875.0	350.0	-	-	-	1225.0
South Bogs	75.0	-	-	-	-	75.0
Total	**19750.0**	**16680.0**	**8275.0**	**5625.0**	**18000.0**	**68330.0**

Table 1-5. Contamination by Sr^{90}.

Concentration Intervals Ci/Km^2)	0.05-.50	0.50-1.0	1.0-3.0	<3.0	Sum
Region	**Contamination of Sr^{90} Measured in Square Kilometers**				
Polissya	125.0	-	-	-	125.0
Korosten'	312.5	312.5	312.5	-	937.5
Upper-Prypiat	187.5	156.3	-	-	943.8
Kiev	687.5	625.0	2500.0	1875.0	5687.5
Carpathian	15.6	-	-	-	15.6
Chernigov	437.6	-	312.5	-	750.1
Ternopol	31.3	-	-	-	31.3
Podilsk	812.5	156.3	-	-	968.8
Lviv	-	-	-	-	-
Mukachev	-	-	-	-	-
Pridneprov	281.3	156.3	-	-	437.6
Avratynsk	812.5	625.0	-	-	1437.5
Samarskij	-	-	-	-	-
Donetsk	-	-	-	-	-
South Bogs	15.6	-	-	-	15.6
Total	**3718.9**	**2031.4**	**3125.0**	**1875.0**	**10750.3**

Measurements for Table 1-6 (Sobodovych et al., 1992) were taken in May, 1986, a few weeks after the Chernobyl disaster; these show radionuclides in the suburbs of Kiev, approximately 15 to 20 kilometers from Kiev's center.

Table 1-6. Radionuclide activity in suburbs of Kiev: May, 1986.

Type of test	Location: S-SE Koncha-Zaspa (Ci/km^2)	Location: N-NE Puscha-Wodyca (Ci/km^2)
Ground (0-3cm deep)	3.08×10^{-8}	0.51×10^{-7}
Ground (3-10cm deep)	1.22×10^{-3}	0.69×10^{-7}
Pine trees	1.00×10^{-3}	4.54×10^{-6}
Pine tree bark	2.63×10^{-7}	0.71×10^{-6}
Carpet	1.00×10^{-3}	0.95×10^{-5}
Grass	4.97×10^{-6}	0.93×10^{-5}

Note: These suburbs are located 15-20 km from Kiev.

Finally, tritium, a radioactive isotope of hydrogen, was present at Chernobyl (Woytsenhowich, 1991). Tritium emits negative beta particles of 19,000 electron volts of energy and has a half-life of 12.5 years. Table 1-7 (Sobodovych et al., 1992) shows the testing of water contaminated by tritium. Since tritium naturally occurs in water, probably the action of cosmic rays on atmospheric hydrogen, one would need prior testing to determine if these measurements were significant. If they were significant, the dates of these measurements might indicate serious problems.

Table 1-7. Contamination of water by tritium.

Type of Water	Date of test	Number of test	Concentration (Bk/Liter)	
			Range	Median
1. Atmospheric (Snow, Water)	Jan 92-Feb 92	51	2.7 to 6.4	3.5
2. Surface Water	Nov 91-Jan 92	124	2.7 to 11.8	4.8
3. Ground Water	Nov 91-Jan 92	101	2.7 to 12.7	5.1
4. Underground Water	Sep 91-Jan 92	68	2.2 to 5.2	2.2

Within weeks following the Chernobyl disaster, measurements to assess damage to forests surrounding the area were taken. Ultimately, about 500 hectars of forests were destroyed as a result of the accident. The government established a 30-kilometer fenced zone around the reactor with military patrols, whose purpose was to prevent unauthorized access. Even outside this zone, the density of contamination was 10 to 80 Ci/km^2. At least 28,000 km^2 of forest were contaminated.

The first reported measurement of gamma radiation occurred on May 16, 1986, 20 days post-accident (Sobodovych, 1992). Two devices were used for measurements. The first device, the Russian Army DP-5B, was available to units working in nuclear contaminated battlefields where it was used for rough estimates of nuclear contamination. The second device, SRP-6801, yielded more precise measurements and was carried by engineers who surveyed the site. Table 1-8 shows the results for measurements inside the 30-kilometer zone and adjacent forest areas. Approximately 100 hectare grids were laid out on maps by the Ministry of Forest. A sampling technique was then utilized. The number in parentheses following the forest name in the first column denotes the grid area.

Table 1-8. Measurement of gamma radiation for 30-km zone and adjacent areas, May 16, 1986.

Location of the measurement	DP-58 (millirads/hr) Army device	SRP-6801 (millirads/hr) (more precise)
1. Polissia Forest (18)		
Meadows	0.14	0.20
Free in air	0.10	0.25
Grass	0.12	0.25
Carpet	0.20	Not Measured
2. Radynskoye forest (12)		
Forest edge	0.13	0.25
Meadows	0.20	0.41
Trees	0.26	0.44
Carpet	0.22	0.42
Village of Cheremoshe	0.20	0.38
3. Radynskoye forest		
Edge of pine trees	0.75	1.25
Young mixed trees	0.75	1.50
Free in air	0.75	1.40
Crown of trees	0.75	1.45
Grass	0.80	1.50
Moss	1.50	1.50
Oat field	0.45	1.25
Ground	0.70	0.70

Note: numbers in parentheses show grid number denoting location of sampling squares.

Table 1-9 (Sobodovych, 1992) shows gamma radiation in forests south of the reactor. Measurements were also made in May, 1986. These forests contain coniferous trees, which are especially vulnerable to radiation. This table is useful because the distance from the reactor is measured, as well as the growth of pine trees in a particular forest.

Table 1-9. Gamma radiation in forest south of Chernobyl at various distances: May,1986; Device: DP-58 (millirads/hr).

Location	Free in air	Carpet
1. Dymer forest (100 km*) Pine trees-50 years old	0.6	1.0
2. Ivankov forest (80 km*) Pine trees-80 years old Pine trees-50 years old Pine trees-18 years old	0.7 1.5 1.3	0.7 2.8 3.2
3. Chernobyl forest (20 km*) Pine trees-30 years old	3.5	10.0
4. Novoshepelychi forest (10 km*) Pine trees-30 years old	10.0	30.0

Note: * denotes kilometers from reactor to center of forest.

Table 1-10 is extremely interesting, since it shows the result of forest damage within the 30- kilometer zone. It was constructed based on conversations with Mr. Kaletnik. This table was cited in the Pacific-Sierra Research Corporation's analysis of Landsat imagery (McClellan, G.E. et al., 1994). The distance from the reactor site is approximately one kilometer, and as Table 10 reflects, 100% of the trees located 350 meters from the edge of the forest were recovered and sent to mills to be used as lumber. The rest of the trees were bulldozed into large pits and covered with topsoil. This action has increased ground contamination, and the Ukrainians are presently reviewing options to deal with this situation.

Table 1-10. Result of forest damage by radiation within the 30-kilometer zone.

Distance from the edge of the forest	Calculated absorbed Dose—Rad x 10^3	% of tree crown damage	Degree of harm	% of recovered trees
Edge of forest	10	100	Completely dry Wood	0
35 meters	6.5	50	Very strong	25
90 meters	4.9	20-30	Medium	50
350 meters	0.5	Up to 10	Small	100

In 1986, the crowns of trees contained about 50% of the radionuclides (Yakovlev, 1992). By 1988, 95% of the radionuclides were in humus or carpet. Today, most radionuclide content of the foliage has migrated through the root system.

Beginning in the summer of 1988 measurements were made of radioactive particles within the 30-kilometer zone in an area called the "Brown Forest", so named because the leaves and vegetation were discolored by radiation. Table 1-11 (Sobodovych, 1992) shows the results of these measurements, with the percentages of each isotope listed. The table also displays the particle properties as either irregular shaped flakes or round balls with varying composition of beryllium, cuprum, lead, silicon, tantalum, and iron. High concentrations of cerium, cesium, and ruthenium are shown.

Table 1-11. Radioactive particles from the brown forest.

Date of Test	Form, size (mcm), and properties of particles	Basis of particle	Element (percentages)				
			Ce^{144}	Cs^{134}	Cs^{137}	Ru^{106}	Co^{60}
Jun 1988	Black, hard, magnetic balls, 46.7 mcm	Oxides of Fe	2.0	-	2.0	94.0	2.0
Aug 1988	Irregular, 1.2-6.5 mcm and Balls, 4.1-5 mcm, dark br	Be, Pb, Cu	54.2	5.4	15.5	24.9	-
Jan 1989	Irregular, 1.6-88.0 mcm, dark br, nonmagnetic	Fe, Si, Pb	50.0	4.5	22.3	29.0	-
Jan 1989	Irregular, fragile, black, Nnnmagnetic, 2.0-20 mcm, Balls, 1.0-4.0 mcm	Fe, Si	4.0	8.9	92.6	24.5	-
Jan 1989	Irregular, 1.2-6.4 mcm, dense, black, with balls, 0.6-2.4 mcm	Si, Ta	88.2	0.8	3.8	7.2	-

Table 1-12 (Sobodovych, 1992) displays a list of forests contaminated by Cs^{137} and the levels of contamination. These measurements were made in 1990 and 1991. Figures for 1992 were not available.

Table 1-13 (Woytsehowich, 1991) shows measurements taken from Kiev in 1991 in which foliage samples were collected, burned, and analyzed for Sr^{90} and Pu. These measurements were taken in three parks in Kiev proper. Leningradskaya Square is in the center of downtown Kiev, and the hydropark lies along the Dneiper River to the east of downtown.

Finally, Tables 1-14 and 1-15 (Baryahtar & Bobyleva, 1991) reflect the Ukrainians' concern with individuals growing, harvesting, and consuming food from contaminated areas.

Blackberries, mushrooms, and medical herbs were chosen for analysis because they are both plentiful and susceptible to the effects of radioactive contamination. The transition coefficient presented in these tables was designed to give a "density rating" by converting measurements taken in square meters to more useful kilograms. The specific activity for Cs^{137} is listed in becquerels per kilogram, with a level of confidence as shown.

Table 1-12. Contamination of forests by Cs^{137}.

Region	Year	Total area of forest hector x 10^3	Studied Area	Levels of Contamination Ci/km^2) <1.0	1.0-2.0	2.01-5.0	5.01-10.0	10.01-15.0	15.01-40.0	40.01-80.0
Zhyto-mir	1990	735.14	735.14	251.01	188.78	201.50	-	69.05	16.79	7.83
	1991	732.36	732.36	293.03	182.49	187.41	21.22	16.43	27.02	4.76
Kiev	1990	940.57	940.57	107.07	149.93	67.10	-	13.57	2.09	0.81
	1991	427.77	427.77	241.23	107.47	52.36	15.25	5.11	3.54	2.81
Rovno	1990	549.96	549.96	35.40	279.60	218.10	-	16.86	-	-
	1991	671.53	671.53	293.57	215.29	151.61	10.79	0.33	-	-
Cher-nigov	1990	276.40	276.40	187.91	33.99	47.70	-	6.80	-	-
	1991	988.93	988.93	919.35	43.23	22.79	2.70	0.80	.06	-
Cher-assy	1990	46.25	46.25	21.50	17.10	6.20	-	1.45	-	-
	1991	220.35	220.35	190.06	22.59	6.90	0.76	0.04	-	-
Vin-nitsa	1990	77.80	77.80	77.80	-	-	-	-	-	-
	1991	216.34	211.34	179.43	25.07	6.20	0.42	-	-	-
Volyn	1990	-	-	-	-	-	-	-	-	-
	1991	173.07	173.07	131.52	36.70	4.85	-	-	-	-
Total in 10^3 Hec-tors	**1990**	**2026.12**	**2026.1**	**680.69**	**669.40**	**540.61**	**-**	**107.7**	**18.88**	**8.64**
	%Area			**33.60**	**33.00**	**26.70**	**0.00**	**5.31**	**1.00**	**<1.00**
	1991	**2839.58**	**2825.1**	**1648.2**	**632.84**	**432.12**	**51.08**	**22.71**	**30.62**	**7.57**
	%Area			**58.34**	**22.40**	**15.29**	**1.80**	**<1.00**	**1.08**	**<1.00**

Table 1-13. Concentration of Sr^{90} and Pu in 1991 Kiev foliage.

Location	Weight of dry sample	Weight of ash	Sr^{90} (Bk/kg)	Pu (Bk/kg)
Leningradskaya square	987 gr	120 gr	2.5-22.9	0.03-0.10
Lesnoy district	638 gr	67 gr	4.6-49.4	0.05-0.22
Hydropark	836 gr	90 gr	-	0.05-0.39

Note: Free-in-Air: Pu = 10-70 Bk/m^3 or 10^{-13} to 10^{-12} Ci/liter

Table 1-14. Contamination of Cs^{137} in berries, mushrooms, and medical herbs.

	Contamination in Ci/km^2				
	<=2	**2-5**	**5-10**	**10-15**	**15-20**
Number of tests-Blackberries	19	11	10	8	6
Specific activity of Cs^{137}	364 +/- 64	1029 +/- 189	1776 +/- 189	7949 +/- 1361	8222 +/- 2950
Transition coefficient	0.49	0.92	0.67	1.86	0.91
Number of tests-Mushrooms	41	33	14	17	8
Specific activity of Cs^{137}	326 +/- 224	2998 +/- 548	4997 +/- 675	19990 +/- 3800	97211 +/- 9214
Transition coefficient	1.12	2.70	1.91	3.15	4.10
Number of tests-Herbs	23	30	12	2	2
Specific activity of Cs^{137}	768 +/- 182	1840 +/- 496	1929 +/- 720	12256 +/- 897	18442 +/- 3141
Transition coefficient	1.06	0.99	1.04	2.21	1.25

Note: Transition Coefficient = dm^2 / kg = decimeter^2 / kilogram = density

Table 1-15. Contamination of Cs^{137} in wood.

	Contamination in Ci/km^2			
	<=2	2-5	5-10	10-15
Number of tests-wood with bark	26	26	20	7
Specific activity of Cs^{137}	171 +/- 29	503 +/- 91	1094 +/- 112	2674 +/- 394
Transition coefficient	0.23	0.27	0.28	0.48
Number of tests-wood without bark	21	25	9	-
Specific activity of Cs^{137}	57 +/- 10	181 +/- 40	608 +/- 147	-
Transition coefficient	0.08	0.09	0.16	-

Note: Transition coefficient = dm^2 / kg = $decimeter^2$ / kilogram = density

Seven years after the Chernobyl accident, approximately 7,000 people had died as a result of radiation-related illnesses. In 1988, 35% of the adult population and 43% of children were considered healthy in the Kiev region (Awramenko, 1992). In 1989, these figures were substantially lower according to government sources; however, no percentages were available to substantiate this claim.

Research shows that adults suffer from heart, blood vessel, respiratory, and digestive diseases. The number of hypertensive cases has doubled, while the number of malignant tumors has increased 11.2% in the last two years (Awramenko, 1992). According to Baryahtar & Bobyleva (1991), since the accident, medical and pathology reports confirm that the number of blood diseases increased 14.3%. The number of cases of lymphatic disease increased 45.1%, acute leukemia disease increased 14%, and endocrine cases increased substantially. From 1990-1991, nephralgia doubled, while the number of nervous system disorders increased 10 times among adults and 11 times among children. Children suffer from all of these diseases in addition to visual problems, inflammation of the joints, and increased infectious diseases. To the north of Kiev, closer to the accident site, the number of children with infectious diseases increased four times since the accident and is 96% higher than other regions of the country. Of that number, 59% suffer from anemia, which has increased 5 - 10 times among children since the Chernobyl accident.

The thyroid gland is especially sensitive to radioactive iodine found in nuclear contamination. Many adults and children received equivalent doses of over 200 rems. Goiter among children increased three times between 1989-1991, and hypothyroidism increased six times for the same period. Thyroid cancer among children has increased from 24 cases in 1990 to 70 cases in 1991.

Prior to 1991 there were no cases of internal organ cancers among children, yet today it ranks as the second largest cause of infant mortality. In 1991, 37.1% of newborns evidenced some kind of pathology and in Kiev there were 2,500 premature deliveries. Anemia increased four times among pregnant women post-Chernobyl.

According to Ukrainian law, individuals who were employed at Chernobyl and those involved in the clean-up efforts were divided into five categories depending on the amount of radiation absorbed. Category I individuals were assigned to Chernobyl when the accident occurred and received at least 25 Gy of radiation. Category II were men who were assigned clean-up duties who also received 25 Gy or more of radiation. Category III were individuals who received between 10 and 24.9 Gy of radiation. Category IV were individuals who received between 5.0 and 9.9 Gy, and Category V were those individuals who received between 0.1 and 4.9 Gy. One Gy is equivalent to 100 rads.

According to the Office of Chernobyl Affairs in Kiev, the new disease rates for individuals who received at least 25 Gy has doubled over those receiving less dosages. The relationship between absorbed dose and effect has only been investigated since 1990. In 1990, it was noted that increased oncological rates were attributed to men who received 25 Gy or more and to women who received 10 Gy or more. Generally, endocrine disease rates among male clean-up crew workers increased almost 4 times the 1988 rate. The endocrine disease rate among women who received 10 Gy or more has doubled each year between 1989 to 1990. Category II personnel were 80 - 100% more likely to suffer from digestive and nervous system diseases than individuals in other categories. In the Kiev, Zhytomir, and Chernigov regions the rates for newly acquired diseases for Category V are 26.2% hematic system, 18.2% respiratory system, and 12.6% nervous and digestive system (Baryahtar & Bobyleva, 1991). The maximum disease rates are in Ivankov, Polissia, Narodichi, and Ovruch. In the Rovno region, the lowest newly acquired disease rates were reported among children born in 1984 and 1985. Disease rates for children born after the Chernobyl accident were 1.5 to 3.0 times higher than those born prior. In the same region, respiratory illness among children accounts for 25 - 40% of all new illnesses, especially among children 1 - 3 years of age where they present with respiratory problems 8 - 10 times per year. The other sixty percent of children present with thyroid gland problems. Anemia has increased among children 2.5 to 3.2 times between 1985 and 1988.

Ukrainian law also divides people who suffered from Chernobyl into another five-group categorization. Group A includes 5,237 disabled individuals, 187 people diagnosed with acute radiation symptoms, and 15,000 people who suffered diseases directly attributed to the Chernobyl accident. Group B includes 180,000 personnel who took part in the clean-up efforts, 130,000 people who received doses in excess of 250 mSv and were relocated from areas inside the 30 kilometer zone, and 12,000 children born to parents involved in the clean-up effort. Group C includes children who have thyroid gland radiation in excess of allowable standards, 60,000 people who took part in the clean-up effort from 1988 until 1990 who received less dosages than those who were first on the scene, and approximately one million people who currently live in contaminated areas but who await relocation. Among them are 350,000 children, 65,000 of whom were born after the accident. Group D includes 1.5 million persons who work or live permanently in areas still receiving radio-ecological monitoring, in addition to their 400,000 children. Some government figures include in Group D all the inhabitants of the Kiev, Chernigov, and Zhytomir regions, or approximately another 4.5 million people.

In 1990, the fifth group was added, comprised of women, when it was realized they showed the highest rates for new respiratory and digestive systems diseases for ages of 30 - 39. Today, the Ukrainian registry contains the names of 347,619 civilians who suffered direct medical problems as a result of Chernobyl, plus 36,000 military personnel who were also affected.

Table 1-16 (Awramenko, 1992) shows the newly acquired disease rates for relocated persons. These individuals lived in contaminated areas but were forced to relocate because of excessive levels of radiation. Most of these individuals belong to Group D and the majority of them have been relocated.

Table 1-16. Disease rates for relocated individuals.

Disease	1986	1990	Percent increase
Heart and blood	0.74/1000	6.94/1000	938 %
Endocrine, digestion, Immune	12.67/1000	171.11/1000	1350 %
Respiratory	23.67/1000	136.68/1000	577 %
Nervous	21.25/1000	106.28/1000	500 %

Table 1-17 (Awramenko, 1992) shows the disease rates for those people relocated to Kiev.

Table 1-17. Disease rates among individuals relocated to Kiev.

Disease	1986	1990	Percentage Increase
Endocrine system	11.79/1000	119.73/1000	1016 %
Respiratory system	26,89/1000	163.16/1000	607 %

Finally, Table 1-18 (Awramenko, 1992) shows the relative health of these four groups from 1988 to 1991. Year-to-year percentages are decreasing due to survival rate.

Table 1-18. Percentages of individuals who are considered healthy.

Groups	1988	1989	1990	1991
Group A	74.0	66.4	52.8	33.8
Group B				
Adults	61.5	44.1	35.3	28.8
Children	-	43.9	35.2	29.1
Group C				
Adults	35.4	35.4	26.0	31.7
Children	-	52.9	40.7	39.8
Group D (Only 400,000 children were tested)	-	77.7	62.9	48.5

As of January 1, 1992, 1,536,270 persons were registered by the Ukrainian government as having suffered medical problems as a result of Chernobyl. Among those were 350,225 children and 180,144 personnel assigned clean-up duties after the Chernobyl accident (Awramenko, 1992).

Seventy percent of workers in the Narodichi forest in the Zhytomir region received 0.44 rads per year of radiation, and 10% received more than 2.3 rads per year (Yakovlev, 1992). The highest content of Cs^{137} was absorbed by woodcutters and forestry workers in the Rovno region which contains two forests, the Vladimiretsky and Dubrovitsky. These workers received between 31.8 and 74.2 Bk/kg.

Ukrainian law divides all forests into four categories, dependent on Cs^{137} dose. Category I includes the Pollessky and Narodichi forests, where contamination exceeds 40 Ci/km^2. Category II contains the Dymer, Ivankov, Ovruch, Luginsk, and Slovechansky forests, where active monitoring shows contamination between 15 and 40 Ci/km^2. Category III includes forests with contamination between 5 and 15 Ci/km^2. These forests require continuous monitoring. Category IV consists of forests containing no more than 5 Ci/km^2. The Ministry of Forests in Kiev is concerned about forest workers who have monitoring and woodcutting duties in contaminated forests.

In the 10 years following the Chernobyl nuclear accident (as of 1996), the number of healthy individuals living in contaminated areas decreased from 67.1% to 33.1%. Chronic pathologies increased from 31.5% to 66.0%.

Most cases reflect pathologies of the endocrine system, blood and blood-generating systems, nervous system, and gastroenterological system.The most substantial growth of this dangerous statistics is related to young people aged 15-17 years--6.6 times normal (8.1 times for boys and 5.6 times among girls). Death rates and disability rates have increased substantially (about 2.5-3.5 times), as compared to those of people who lived in normal conditions. Pathology of the thyroid gland constitutes 72.7% of all endocrine cases for women, and 62.5% for men.

As of 1998, the official death rate among the "Eliminators" (who are still alive) is 1.8 (80% higher than normal). This is primarily due to higher incidences of cancer, diseases of blood and blood-generating organs, and pneumonia.

The present study, an ongoing longitudinal project which commenced in 1995, entails assessments of neuropsychological and physical capabilities of four independent volunteer participant groups. The control group (Controls) consists of healthy volunteers that reside outside the immediate radiation exposure area. The second group consists of "Eliminators," who are individuals who were involved in the tasks of removing nuclear debris and assisting in construction of the containment chamber for the defective reactor facility. The third group of volunteers consists of Forestry workers who perform monitoring, woodcutting, and other related activities in the Narodichi forest, which is in close proximity of Chernobyl. It is known that 70% of workers in the Narodichi forest (in the Zhytomir region) received approximately 0.44 rads per year of radiation, and 10% received more than 2.3 rads per year (Yakovlev, 1992). Finally, the fourth group is comprised of Agricultural workers from Rozumnytsia, which is approximately 150 km south of Kiev, and for whom knowledge of the level of radionuclide is known.

The instrument that was chosen to be the primary measure of cognitive performance is the Automated Neuropsychological Assessment Metrics (ANAM) Battery, which is a subset of the Office of Military Performance Assessment Technology (OMPAT) Tester's Workbench (TWB). The TWB is a library of automated tests that has been constructed to meet the need for precise measurements of cognitive processing efficiency. The ANAM batteries are unique combinations of TWB tests that have been configured for neurocognitive assessment and evaluation of functioning in a variety of neuropsychological domains. Many of the component tests in ANAM were derived from the Unified Tri-Service Cognitive Performance Assessment Battery (UTCPAB; Reeves et al. 1991) and the Walter Reed Performance Assessment Battery (Thorne et al. 1985). The Ukrainian subset of ANAM (ANAMUKR) was designed by Reeves and Gamache (1994), and constitutes a specialized subset of the TWB-ANAM batteries. It consists of tests that have been configured for repeated measures testing for neurocognitive impairment due to exposure to radionuclides. It has been designed to assess levels of neurocognitive function ranging from superior to moderately impaired. ANAMUKR subtests also include a stand-alone module for assessing sustained attention (Running Memory Continuous Performance Test).

In the present study, the ANAMUKR battery was combined with the Gamache Physical Abilities Battery (GPAB; Gamache, 1993), for testing the physical capabilities of individuals exposed to radionuclides. This battery, composed of tests derived from Fleishman and Quaintance (1984), is especially sensitive to the physical decrements in performance resulting from exposure to radionuclide contamination. The GPAB consists of tests designed to measure explosive strength (broadjump), static strength (carrying weight), dynamic strength (squat thrusts), and gross body equilibrium (balance beam).

In this report, we describe data on the GPAB and ANAMUKR obtained from four independent groups from Ukraine in 1995 (initial test), and in 1996,1997, and 1998 (repeated tests). These data provide a reference point from which to gauge physical and cognitive performance of individuals who may or may not have been exposed to varying levels of ionizing radiation resulting from the nuclear accident at Chernobyl in 1986.

SECTION 2
METHOD

2.1 PARTICIPANTS.

The participants in the initial phase of the study consisted of 127 volunteers (24 females, 103 males) who lived in Ukraine prior to 1986. Ages ranged from 11-61 years, averaging 40.21 years. The four groups into which they were divided included a non-exposed Control group (*AC*); and three exposed (exposure) groups: Eliminators (*AE*), Forestry Workers (*AF*), and Agricultural Workers (*AG*). Demographic information is presented in Table 2-1. Mean dose levels of exposure to radiation (in rads) for each group are included; these are based on the medical records of the individuals.

Table 2-1. Demographic information and mean dose of radiation for the 4 groups – above background radiation.

GROUP →	*AC* (n=31)	*AE* (n=36)	*AF* (n=29)	*AG* (n=31)
Age **Mean (S.D.)**	33.23 (7.86)	40.47 (6.81)	50.83 (7.83)	36.32 (14.26)
Gender **Male** **Female**	 24 7	 33 3	 29 0	 17 14
Mean dose In rads (FIA)	0	62.95	12.61	8.81

These individuals were randomly assigned to their groups, which were counterbalanced by occupation. Further, participants in the control group were assigned to match by occupation, as closely as possible, the exposure participants. For example, if there was a truck driver in any of the three exposure groups, a truck driver was sought as a control. In addition, participants in the control group were matched for age and gender to those in the exposure groups.

2.2. INSTRUMENTS.

2.2.1. Gamache Physical Abilities Battery (GPAB).

Physical testing involved two stations, each equipped with a stop watch and tape measure. Three tests were timed with a stopwatch: balance beam, squat thrusts, and carrying weights. A description of each test in the GPAB is presented in Table 2-2.

Table 2-2. Description of Gamache Physical Abilities Battery (GPAB).

Test	Measurement	Apparatus
Broad jump **(BROADJMP)**	Distance covered in one broad jump (meter)	Designated starting point. Tape measure.
Carrying weight **(CARRYWGT)**	Distance covered in 30 sec. (meter)	10-meter course. participants run back and forth in straight lines carrying 15 kilograms of sand (men) or 10 kilograms (women, children). Tape measure, stop watch, buckets of sand
Squat thrusts **(SQUATTHR)**	Number of squat thrusts in 2 min.	Any area where squat thrusts can be don. stop watch
Balance beam **(BALBEAM)**	Distance covered in 20 sec. (meter)	4-meter board, 12 centimeters wide, 15 centimeters from ground. Tape measure, stop watch.

All physical test scores were recorded in laboratory notebooks. Two observers participated as test administrators for the physical abilities battery. One administrator read instructions to participants and ensured their understanding. The other timed and/or took measurements as appropriate for each test. Independent observer confirmation was required prior to recording scores. All subjects were tested according to standard procedures, with one exception. The hospital where the eliminators resided did not allow buckets of sand on the premises. Therefore, hand-held weights equivalent to the weight carried by other groups were substituted.

2.2.2 Automated Neuropsychological Assessment Battery-Ukraine (ANAMUKR).

The tests in the ANAMUKR battery includes the Stanford Sleepiness Scale (**SLP**), Code Substitution (visual search, immediate recall, and delayed recall: **CDS, CDI, CDD**), Running Memory Continuous Performance Task (**CPT**), Digit Symbol (**DGS**), Matching to Sample (**MSP**), Spatial Processing (**SPD**), Simple Reaction Time (**SRT**), Tapping-Right and Left Index Fingers (**TAPR & TAPL**), and Two-choice Reaction Time (**2CH**). These subtests of ANAM have been described previously (Reeves & Winter, 1992; Levinson & Reeves, 1994). Each session required approximately 60 minutes.

2.3 ASSESSMENT SITES AND ENVIRONMENTS.

Participants in the Control group resided in Ternopil (pop. 250,000). This city is located approximately 450 km west of Kiev, the capital of Ukraine. All testing was conducted in High School Number 22 (Fig. B-7). The Eliminators were tested in the Ukrainian Center for the Radiation Protection of the Population, which is essentially a hospital environment (Fig. B-3). This special hospital is in the suburbs of Kiev, and was established to attend to the medical needs of these individuals. The Forestry Workers were tested in the Ovruch forest, approximately 250km northwest of Kiev. All testing was conducted in their barracks (see Fig. B-8). The Agricultural workers were tested in the village of Rozumnytsia, in the Kiev region, approximately 150 km south of Kiev. The testing site was a farmhouse (Figs B-4, B-5, B-6).

2.4 PROCEDURE.

On days assigned to specific groups, researchers prepared the testing site by installing laptop computers for administration of the ANAMUKR battery (Fig. B-4), and by setting up the apparatus for administration of the physical abilities test battery. A table and two chairs were situated at each of three ANAMUKR testing stations. Each participant sat in one chair and the test administrator sat in the other. This enabled the administrator to ensure that the participant understood instructions and was prepared for testing. Participants were instructed to ask as many questions as necessary to ensure full understanding prior to testing. One table was placed at the entrance for participant registration and orientation, which included having each participant read and sign an informed Consent Form in Russian and English (see Appendix C –only the English version is shown).

During periods when all computer test stations were occupied, participants first completed the GPAB. The rotation of physical testing (i.e., order of balance beam, squat thrusts, etc.) was randomized to the extent that space was available. A rest area was established for participants while awaiting further testing. During test sessions the administrator ensured that there was no discussion among participants about up-coming tests. At the conclusion of the testing sessions, all participants were thanked and given the equivalent of two USA dollars.

The ANAM battery test scores were stored on the hard disk drive of each computer. At the end of the day, all scores were copied to backup 3 ½" floppy disks and marked for that group and year of testing. The backup disks were then re-copied to a second diskette.

Participants in the four groups were tested on the GPAB and ANAMUKR in 1995, 1996, 1997, and again in 1998. All 1995 measures were deemed valid, as were the 1996 GPAB data obtained on the Controls.

Due to extraneous factors, a major portion of the 1996 ANAMUKR data obtained from the Controls was not valid. As a result, these data were not included in analyses of the 1996 ANAMUKR results. Instead, all analyses of the 1996 ANAMUKR performances of the exposure groups relative to the Controls were based on the 1995 Control data. Further, the 1996 GPAB data from the Controls were virtually identical to those obtained in 1995.

Therefore, the same procedure was used in analyses of the 1996 GPAB performances of the exposure groups relative to those of the Controls; i.e., 1995 Control data were also used for these comparisons. For the same reasons, similar analyses were performed on the 1997 and 1998 data. However, for purposes of data analyses based on 4-year averages, all data from all groups were used.

SECTION 3
RESULTS

3.1 OVERVIEW OF 4-YEAR RESULTS: 1995-1998.

The ANAM data files were first consolidated in a computerized spreadsheet and then inspected for completeness and invalid data. Invalid data were defined as "premature responses" which occurred in less than 100 ms, and/or an inordinate number of lapses which indicated that the participant did not understand the instructions for a test prior to administration. This initial screening resulted in unequal numbers of participants associated with each test, but it ensured that the preliminary data presented herein were derived from complete and valid test administrations.

An ANOVA revealed a significant age difference among the groups. Subsequent Scheffe tests indicated that this was due to the higher ages of Group ***AF***, as this group differed significantly from each of the others. No other significant differences in age were observed. Gender composition of the four groups also significantly differed, as revealed by results from a Chi-square test. This is most likely a result of the higher number of females in Group ***AG***, as none of the other groups differed from each other: all were predominantly male. Possible differences between the ***AC***s and ***AE***s on the demographic variables were of particular concern, but none were revealed.

Analyses of 4-year averages for all groups on all measures were performed so as to obtain an overview of how the exposure groups performed relative to the controls on the physical and cognitive measures. Multivariate analyses of variance (MANOVAs) revealed significant differences among the 4 groups on ***all*** measures; further, pairwise comparisons indicated that with only a few exceptions, the average levels of performance of the exposure groups were significantly lower than those of the controls.

Graphic illustrations of actual performance levels of the exposure groups on each task across the 4 years are presented in Figures 3-30 through 3-53, in the section describing the 1998 retest. In each figure, the 4-year averaged performance level of the controls is used as a referent; it is denoted by a dotted line (typically across the top) on each figure.

3.1.1 GPAB.

The 4-year averages for the 4 groups on the physical tasks are presented in Table 3-1. The difference among the groups on **BRODJMP** was significant at the .01 level, while the other differences were significant at the .001 level. Pairwise comparisons of the 4-year averages revealed that with only one exception, all exposure groups performed at significantly lower levels than the controls. The 4-year averages for all groups on all GPAB tasks are graphically illustrated in Figures 3-1 through 3-4.

Table 3-1. Four-year averaged performance on GPAB: physical tasks.

GROUP → TASK	*AC*	*AE*	*AF*	*AG*
BRODJMP (meters)	1.59	1.33	1.43	1.50*
CARRYWGT (meters)	51.61	30.96	40.45	42.51
SQUATTHR (number)	66.66	21.24	40.35	48.41
BALBEAM (meters)	22.19	15.96	20.26	19.13

Note: *not significantly lower than controls.

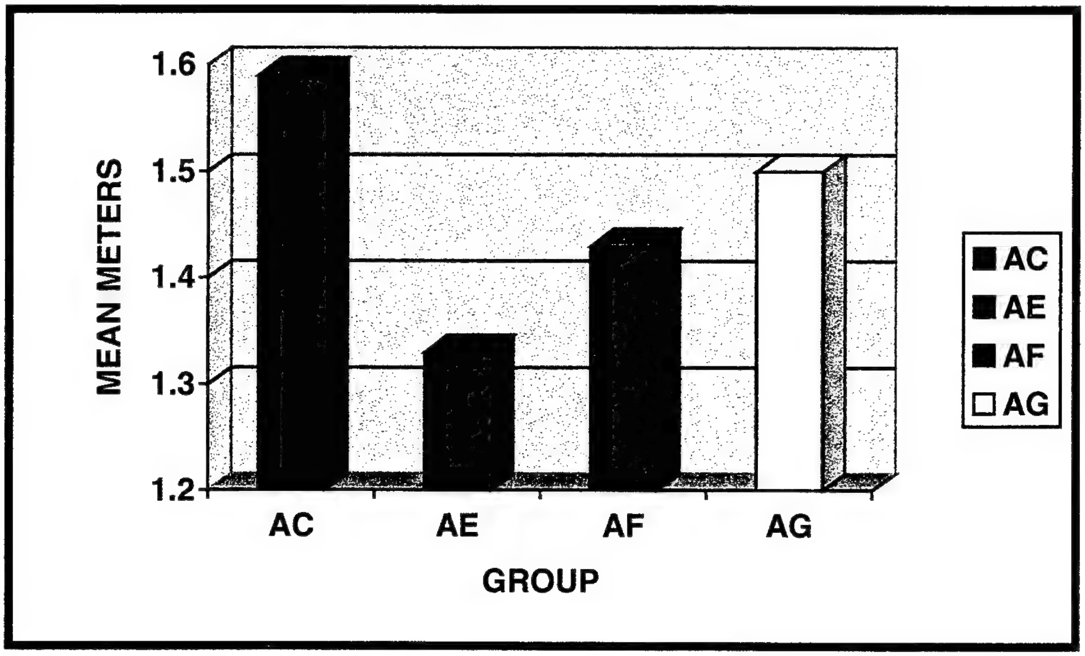

Figure 3-1. 4-year averaged performances on GPAB: BROADJUMP.

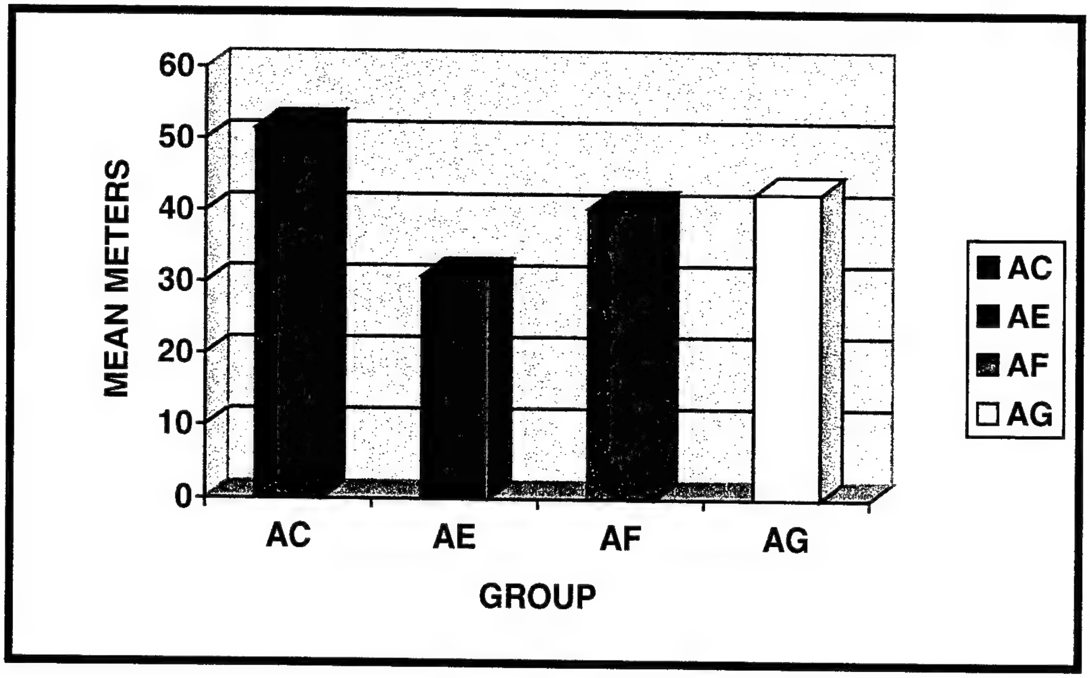

Figure 3-2. 4-year averaged performances on GPAB: CARRYING WEIGHT.

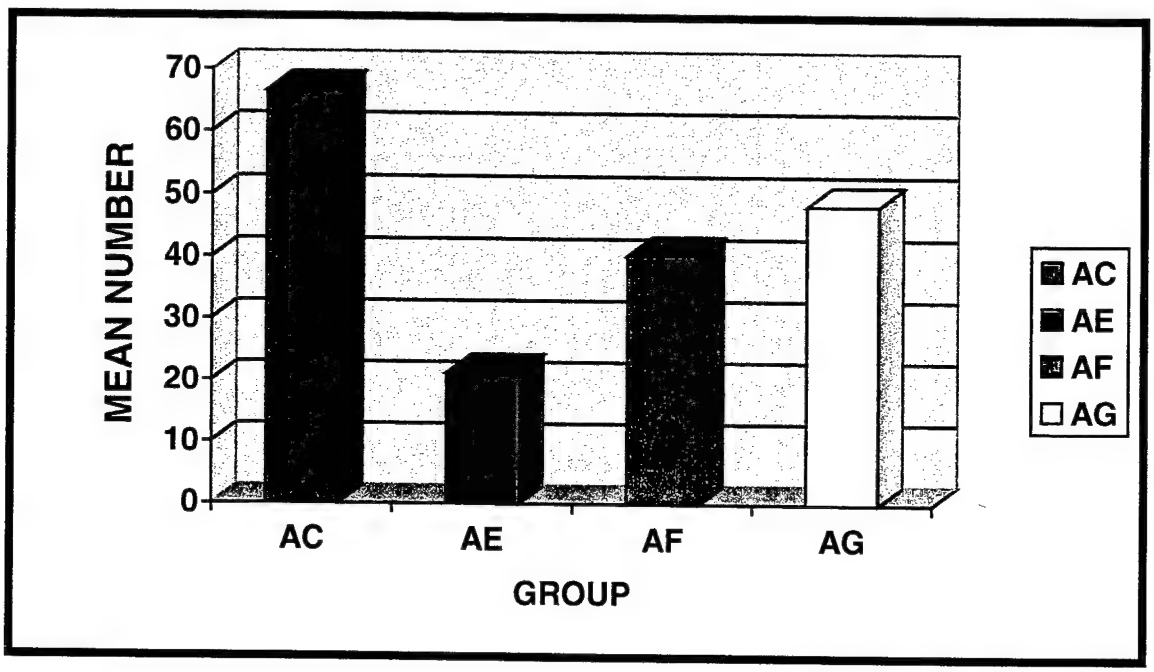

Figure 3- 3. 4-year averaged performances on GPAB: SQUAT THRUSTS.

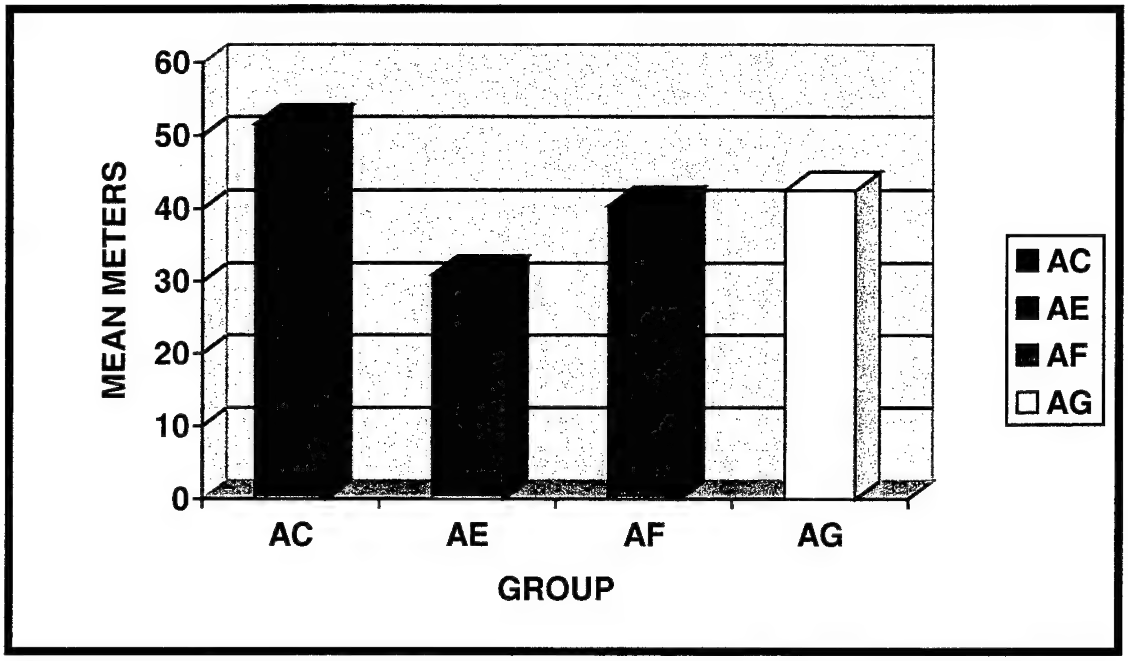

Figure 3-4. 4-year averaged performances on GPAB: BALANCE BEAM.

3.1.2 ANAMUKR: Accuracy.

The 4-year averages for the 4 groups on ANAMUKR-accuracy are presented in Table 3-2. Table 3-2 represents the percentage of correct responses. All differences among groups were significant at the .001 level. Pairwise comparisons of the 4-year averages revealed that, with only 3 exceptions, the exposure groups performed at significantly (most at .001) lower levels than the controls. Figures 3-5 through 3-12 graphically illustrate these findings.

3.1.3 ANAMUKR: Efficiency.

The 4-year averages for the 4 groups on ANAMUKR-efficiency are presented in Table 3-3. Table 3-3 represents correct responses per minute. All differences among groups were significant at the .001 level. Pairwise comparisons of the 4-year averages revealed that, with only 1 exception, the exposure groups performed at significantly (most at .001) lower levels than the controls. Figures 3-13 through 3-21 graphically illustrate these findings.

3.1.4 ANAMUKR: Additional Measures.

Performances averaged over 4 years on the tapping task (right, left), and on the sleepiness scale are presented in Table 3-4. Although all group differences were significant at the .001 level, the levels of the agricultural workers did not differ from those of the controls on any of these measures. The tapping rates for the other exposure groups were significantly (.001) lower that those of the controls, and levels of sleepiness were significantly higher for the Eliminators. These findings are graphically illustrated in Figures 3-22 through 3-24.

Table 3-2. 4-Year averaged performances on ANAMUKR: Accuracy (Percentage of correct responses).

GROUP → TASK	*AC*	*AE*	*AF*	*AG*
2CH	97.36	92.76	92.91	93.98
CDS	96.17	91.14	90.66	95.18*
CDI	91.42	***<u>73.50</u>***	***<u>80.49</u>***	89.01*
CDD	89.24	***<u>72.35</u>***	***<u>78.99</u>***	85.32
CPT	93.66	***<u>77.06</u>***	***<u>86.08</u>***	89.72
DGS	87.96	***<u>73.00</u>***	81.32	80.40
MSP	92.88	***<u>75.33</u>***	84.22	87.68
SPD	88.21	81.18	83.96	91.94*

Note: *not significantly lower than controls. Italicized, bolded, and underlined numbers are considered to suggest clinically meaningful impairment.

Table 3-3. 4-Year averaged performances on ANAMUKR: Efficiency (Correct responses per minute).

GROUP → / TASK	*AC*	*AE*	*AF*	*AG*
SRT	163.51	***<u>111.58</u>***	***<u>111.67</u>***	147.24
2CH	110.62	***<u>76.42</u>***	***<u>80.95</u>***	101.27
CDS	39.58	***<u>24.22</u>***	***<u>26.12</u>***	34.33
CDI	36.42	***<u>18.76</u>***	***<u>24.07</u>***	29.46
CDD	38.19	***<u>20.77</u>***	***<u>26.46</u>***	31.57
CPT	85.22	***<u>58.22</u>***	71.69	79.00
DGS	36.19	***<u>24.28</u>***	30.54	29.30
MSP	38.63	***<u>20.23</u>***	***<u>24.56</u>***	30.31
SPD	27.67	***<u>19.11</u>***	22.81	26.38*

Note: *not significantly lower than controls. Italicized, bolded, and underlined numbers are considered to suggest clinically meaningful impairment.

Table 3-4. 4-Year averaged performances on ANAMUKR: Additional measures.

GROUP → / TASK	*AC*	*AE*	*AF*	*AG*
TAP-R (Mean number of responses in 10 seconds)	57.57	***<u>47.00</u>***	***<u>49.20</u>***	55.23*
TAP-L (Mean number of responses in 10 seconds)	51.50	***<u>41.23</u>***	***<u>42.63</u>***	48.70*
SLP (Scores from 1-7)**	1.63	***<u>2.46</u>***	1.77*	1.69*

Note: *not significantly different than controls.
**higher score = more sleepy. Italicized, bolded, and underlined numbers are considered to suggest clinically meaningful impairment.

3.1.5 A Clinical Neuropsychological Interpretation of Chernobyl-ANAM data.

Overall results from the 4-year averages of ANAM test results, presented in Tables 3-2 through 3-4, provide evidence of clinically meaningful neurocognitive impairment associated with the Eliminator and Forestry groups. The Agricultural group was generally comparable to the Control group. Their test performance did not reveal any meaningful evidence of neuropsychological impairment, and scores were generally within normal limits.

With respect to the Eliminator and Forestry groups, it appears that they have clinically significant neuropsychological deficits in several areas. These include deficits in the ability to sustain high levels of attention/concentration, to encode new information (i.e., learning ability), working memory (i.e., the ability to hold new information in memory for short periods of time), mental flexibility (i.e., the ability to shift mental sets rapidly), and psychomotor speed. The Eliminators are suffering the most severe impairment of neurocognitive and psychomotor abilities. Their test scores revealed impairment of mental power (the ability to produce correct responses to test items) and neurocognitive efficiency (the ability to do both quickly and accurately). In this study mental power was indexed by using percent accuracy scores, which are presented in Table 3-2. Neurocognitive efficiency was indexed by the ANAM "thruput" score, which literally translates to "number of correct responses per minute." These data are presented in Table 3-3. Psychomotor speed data are presented in Table 3-4. These data represent the average number of "Finger Taps" a subject is able to make on a mouse key during 5 consecutive 10 second response trials. Finally, each subject's fatigue level was measured by a Sleepscale score that ranges from 1=very alert and energetic to 7=sleep onset soon. A summary of clinically meaningful deficits for the eliminators is presented below.

3.1.5.1 **<u>Learning and Memory</u>.** The Code Substitution, Learning, Immediate, and Delayed recall subtests were the primary instruments for assessing a subject's ability to learn and retain new information. This test entails having the subjects learn 8 pairs of associated digits and symbols. Following the learning trial, subjects are required to demonstrate the ability to remember the correct pairings immediately and then after a delayed time interval of approximately 20 minutes. Memory scores for immediate and delayed recall trials for Eliminators were 73 & 72% respectively as compared to 91 & 89% for the controls. These results suggest that the Eliminators have an impaired ability to encode, i.e., learn and store new information in short-term memory (e.g., CDI=73%). Although their learning ability is impaired, they are still able to learn and store new information to a certain degree. Further, they are able to retain and retrieve (i.e., remember) the newly learned information over meaningful time intervals. This is indicated by a delayed recall score (i.e., CDD=72%) that nearly matches the immediate recall score (i.e., CDI=73%). These results indicate that they do NOT have a rapid rate of forgetting over retention intervals, as would be the case in Alzheimer's and Alcohol Korsakoff's Dementias. ***The implication is that observed impairments in neurocognitive and memory processes in this sample are NOT a result of chronic alcohol abuse or an Alzheimer's-like CNS disorders.***

3.1.5.2 **<u>Attention/Working Memory</u>.** The Digit Set Comparison Test (DGS) was the primary ANAM subtest used to assess attention and working memory. It is comparable to the traditional Wechsler Adult Intelligence Scale Digit Span subtest. The DGS requires the subject to remember a series of numbers for a few seconds and then determine if a comparison sample is the same or different.

Results from this test indicated that the Eliminators were meaningfully impaired with respect to both percent accuracy (power) and efficiency measures. For example, the Eliminators had an averaged accuracy score of 73% as compared to a Control group score of 87%. Further, the Eliminators had an averaged efficiency score of 24% vs. a score of 36% for the Controls. These results suggest that the Eliminators are experiencing significant difficulties with the ability to attend to and retain information that is not personally meaningful; even for brief periods of time.

3.1.5.3 Mental Flexibility/Executive Function. The Continuous Performance Task was the primary ANAM subtest used for assessing the ability to sustain high levels of concentration and rapidly shift mental sets. These are important "executive" functions that relate to frontal lobe functions. The test requires the subject to rapidly determine if a letter that is displayed on the computer screen is the "same or different" from the letter presented immediately before. Results from this test indicate that the Eliminators have serious deficits regarding the ability to sustain concentration and exercise mental flexibility. For example, the Eliminator's accuracy scores were 77% vs. Control's score of 93%. Further, the Eliminators' efficiency scores were 52 vs. the Control's scores of 85.

3.1.5.4 Level of Subjective Energy. The ANAM Sleep Scale was used to assess the subjects' level of fatigue...i.e., how energized or tired did they feel on a 1-7 scale. The results indicate that the Eliminators felt slightly more tired than the other groups...however, the difference was barely 1 point higher (i.e., the Eliminator average was 2.46). This means that they did not really feel tired. This suggests that observed attention and memory deficits were not due to fatigue.

3.1.5.5 Psychomotor Ability. The ANAM Finger Tapping Test was implemented as the primary test of psychomotor speed. The test requires the subject to "tap" on a mouse key as fast as possible during ten second test trials. The outcome measure is the average number of taps for a ten-second interval. The ANAM test results on this subtest revealed that the Eliminators were much slower that the other groups. For example, their averaged tapping scores for RT and LT index finger tapping were 47 & 41 vs. the Control group scores of 57 & 51. Since their subjective level of fatigue was minimal, results suggest that this psychomotor slowing was not due to being tired.

3.1.5.6 Final Conclusion. The overall results that include loss of mental power and cognitive efficiency and psychomotor slowing strongly suggest impaired brain function. The pattern of impairment is similar to that commonly associated with white matter disease (white matter disease effects the myelin sheaths as a part of neurological functioning).

3.2 CORRELATIONS BETWEEN DOSAGE OF RADIATION AND 4-YEAR AVERAGED PERFORMANCE LEVELS.

For each participant in the study, the level of radiation exposure was obtained from medical records. The original dosage presented on Table 2-1, on page 21, included all subjects. However, our statement of work specifies that the government is interested in low dosage defined as below 70 rads. Therefore we eliminated from Table 2-1 all dosages higher than 70 rads. The following reflects only those dosages less than 70 rads. Mean dosage (and standard deviation) in rads for the four groups were as follows: ***AC***: 0.00 (.00); ***AE***: 43.41 (19.82); ***AF***: 12.61 (2.10); and ***AG***: 8.81 (5.63).

Since the Controls received virtually no radiation, correlations were based only on participants in the 3 combined exposed groups for whom measures on all tasks were obtained for all 4 years of testing, excluding Eliminators receiving over 70 rads. The 4-year average for each exposed individual on each measure was calculated, and these were used to obtain Pearson correlations between each measure and dosage of radiation. In addition, standard multiple regressions were used to calculate the correlations between combined groups of tasks and dosage. The results of these analyses are presented in Table 3-5.

Table 3-5. Correlations between dosage of radiation and performance levels.

TASK	CORRELATION	SIGNIFICANCE
GPAB	**.70**	**.001**
BRODJMP	-.18	--
CARRYWGT	-.34	.01
SQUATTHR	-.55	.001
BALBEAM	-.56	.001
ANAMUKR: ACCURACY	**.71**	**.001**
2CH	-.07	--
CDS	-.38	.01
CDI	-.62	.001
CDD	-.56	.001
CPT	-.47	.001
DGS	-.35	.01
MSP	-.54	.001
SPD	-.52	.001
ANAMUKR: EFFICIENCY	**.68**	**.001**
SRT	-.25	--
2CH	-.44	.001
CDS	-.37	.01
CDI	-.50	.001
CDD	-.50	.001
CPT	-.48	.001
DGS	-.49	.001
MSP	-.45	.001
SPD	-.51	.001
ANAMUKR: OTHER TASKS		
TPR	-.34	.01
TPL	-.37	.01
SLP	.60	.001

Significant correlations were revealed for ***21*** of the 24 measures. The only tasks not significantly correlated with dosage were broadjump, simple reaction time, and 2-choice accuracy.

Unlike the other GPAB tasks, broadjump does not require sustained energy; therefore, it is not surprising that it is not related to dose level. The two ANAMUKR measures not related to dose are the simplest of all the tasks, requiring little effort to complete. Thus one would not expect them to be related to levels of radiation. Although tapping is also relatively simplistic, it requires fine motor coordination. Such coordination is reflective not only of integrity of the cerebral precentral gyri, but also of the cerebellum. Involvement of either of these areas would compromise the ability to perform this task.

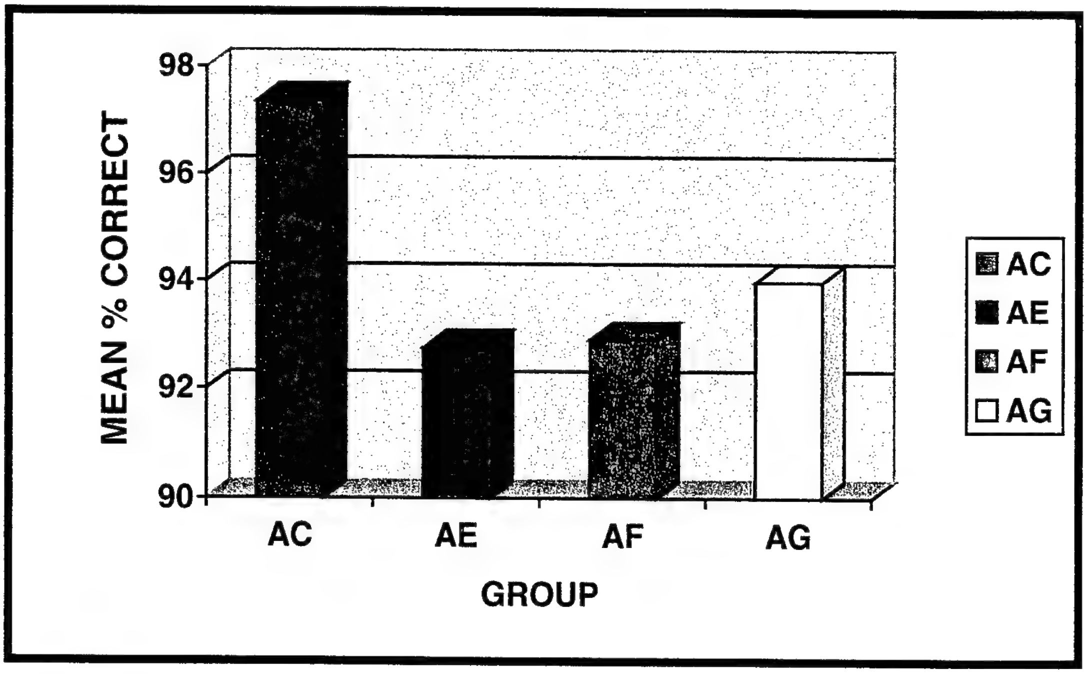

Figure 3-5. 4-year averaged performances on ANAMUKR: 2CH-ACC.

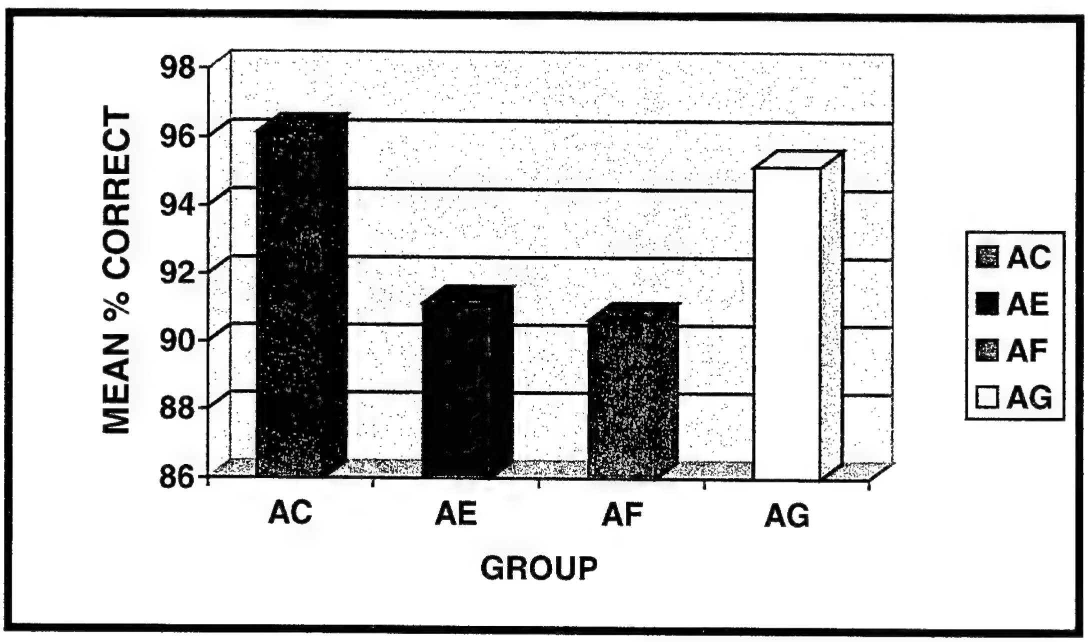

Figure 3-6. 4-year averaged performances on ANAMUKR: CDS-ACC.

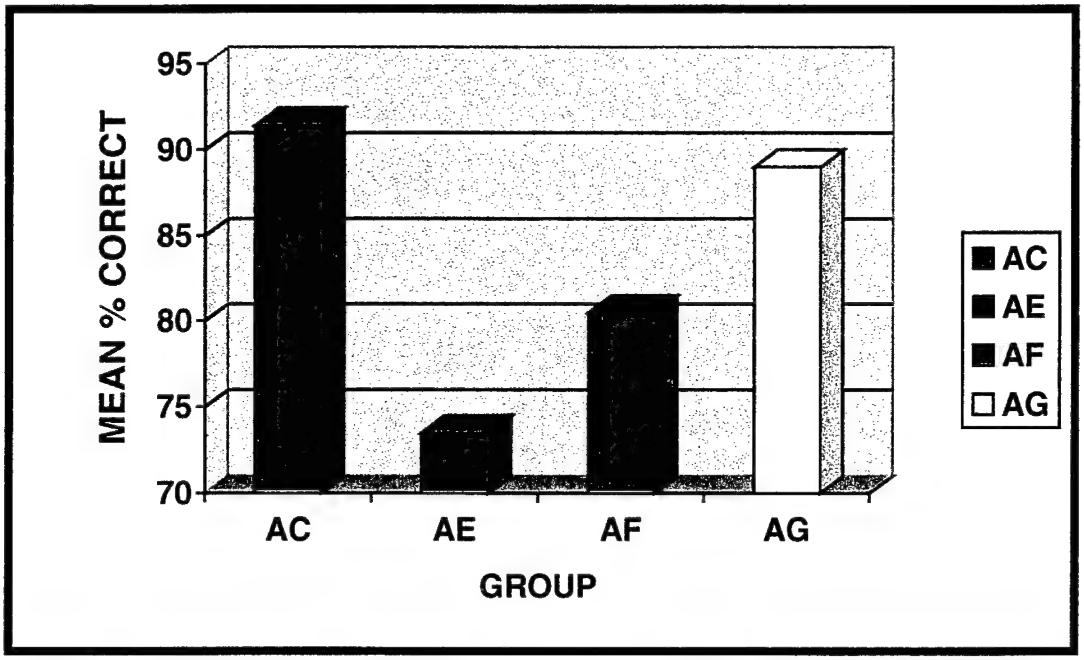

Figure 3-7. 4-year averaged performances on ANAMUKR: CDI-ACC.

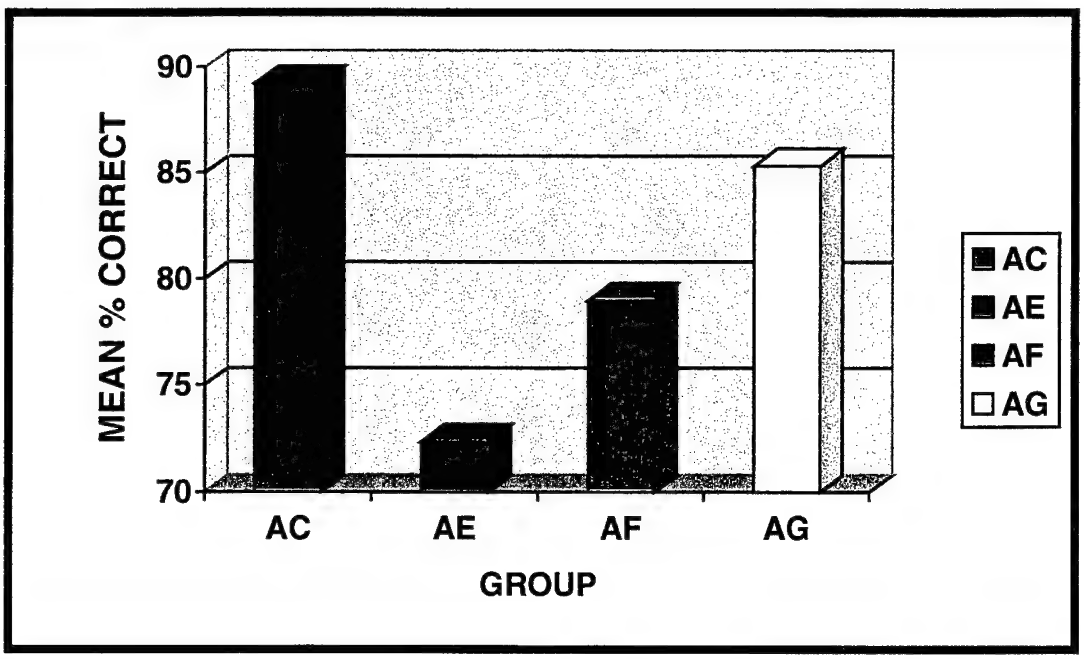

Figure 3-8. 4-year averaged performances on ANAMUKR: CDD-ACC.

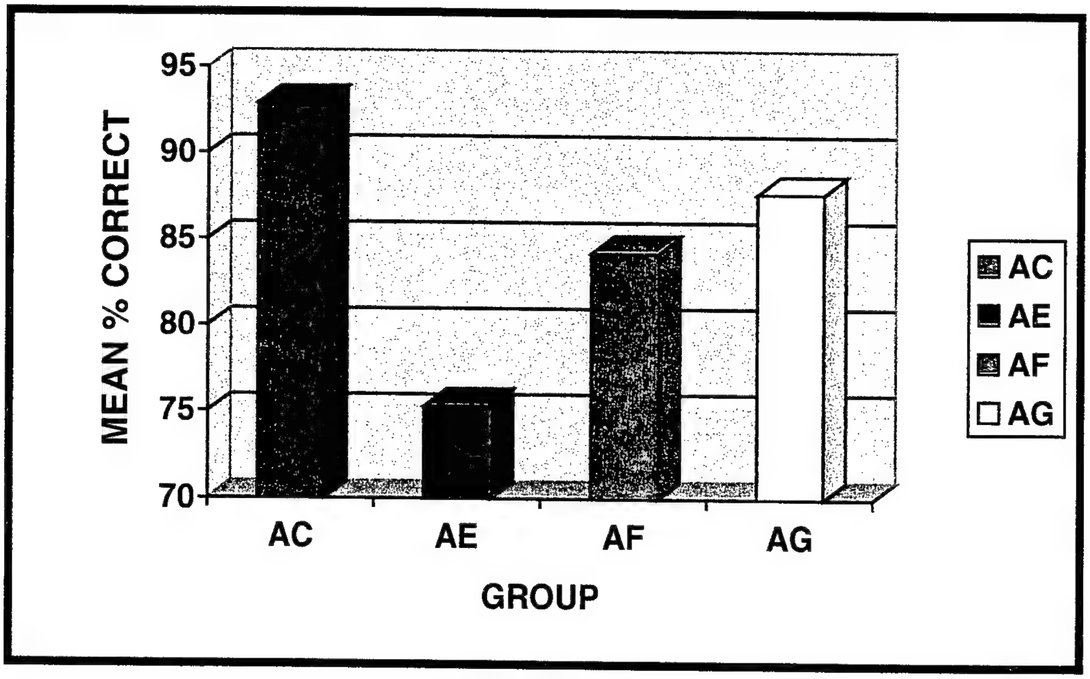

Figure 3-11. 4-year averaged performances on ANAMUKR: MSP-ACC.

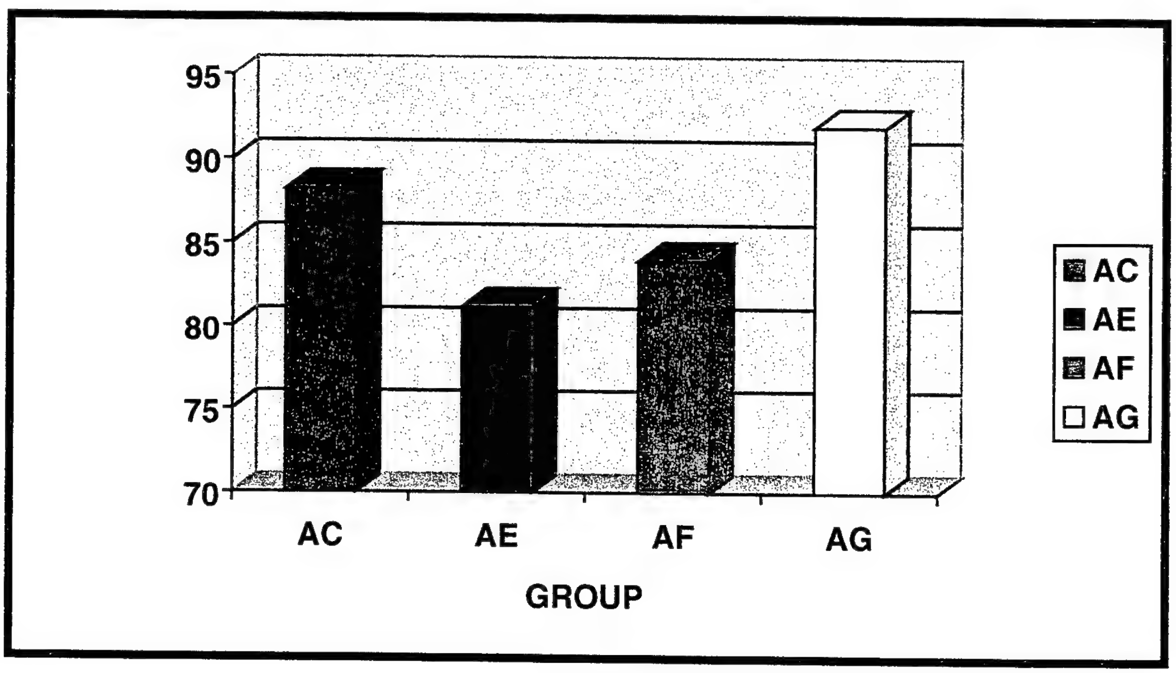

Figure 3-12. 4-year averaged performances on ANAMUKR: SPD-ACC.

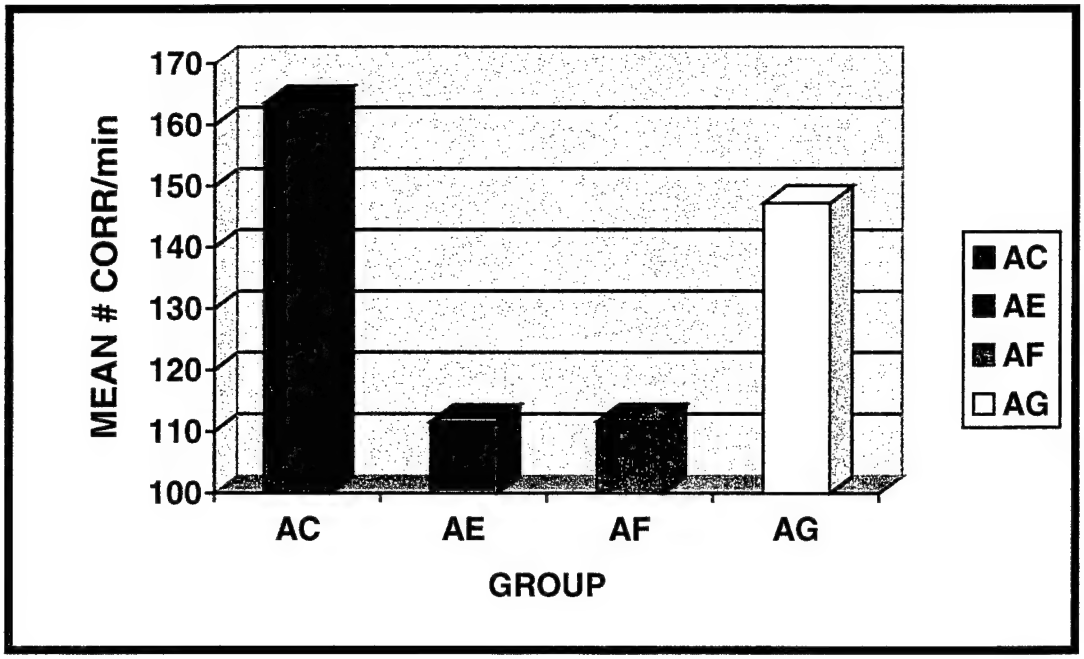

Figure 3-13. 4-year averaged performances on ANAMUKR: SRT-EFF.

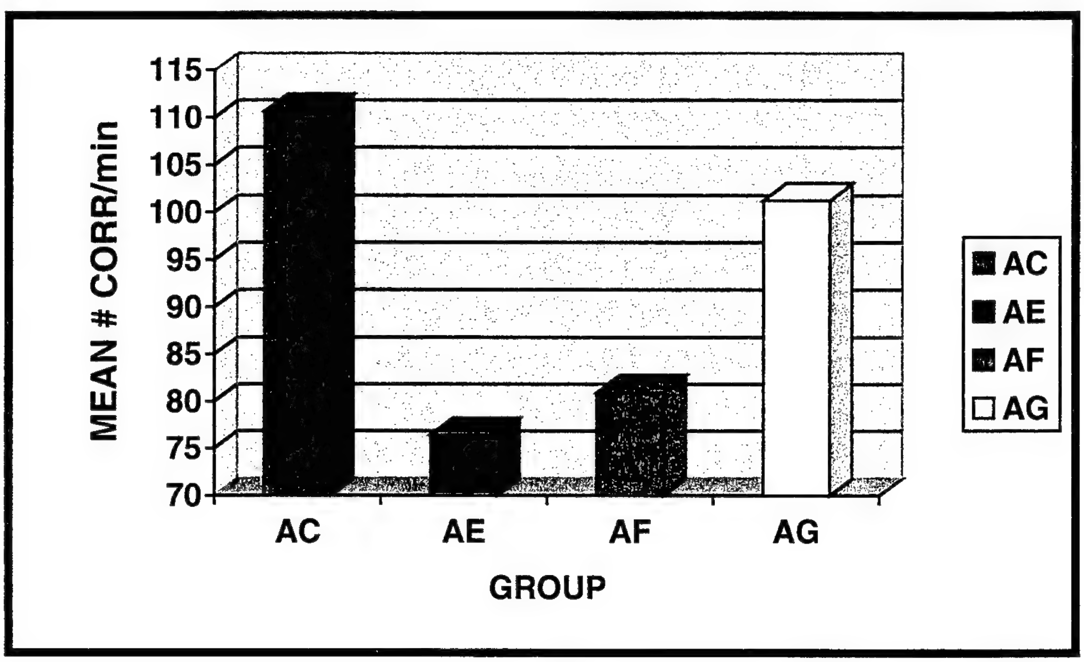

Figure 3-14. 4-year averaged performances on ANAMUKR: 2CH-EFF.

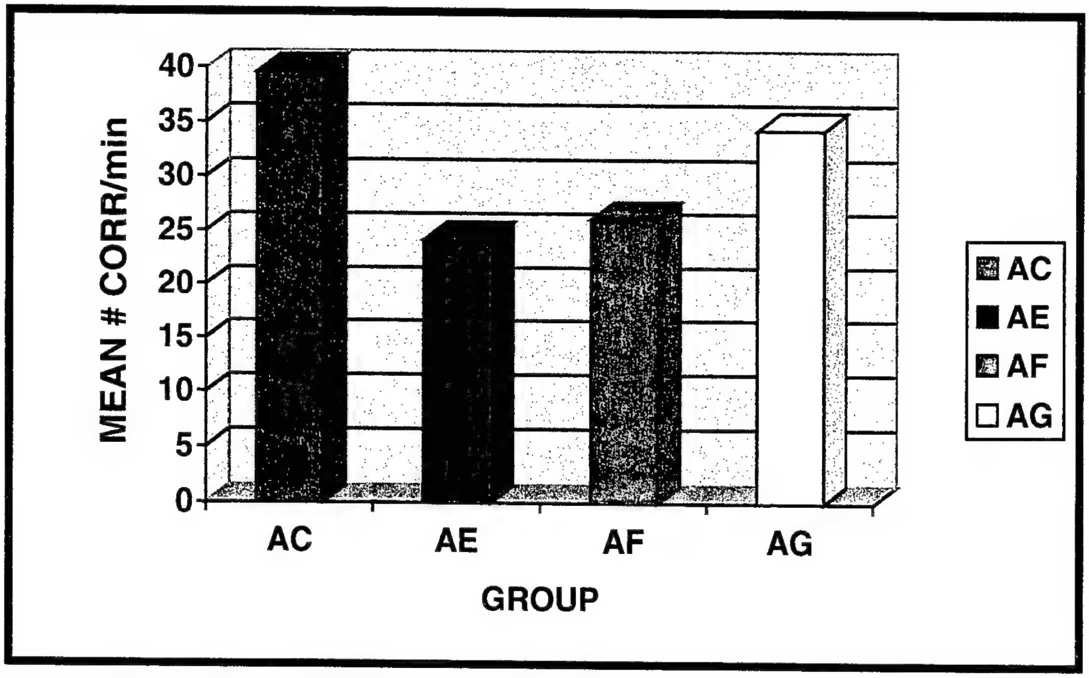

Figure 3-15. 4-year averaged performances on ANAMUKR: CDS-EFF.

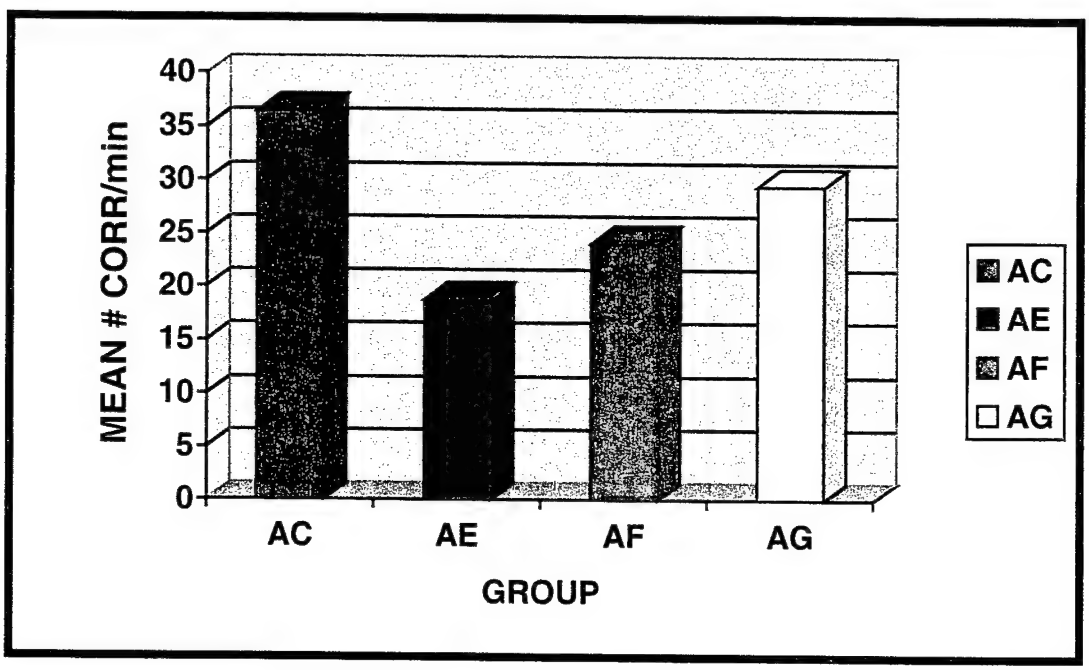

Figure 3-16. 4-year averaged performances on ANAMUKR: CDI-EFF.

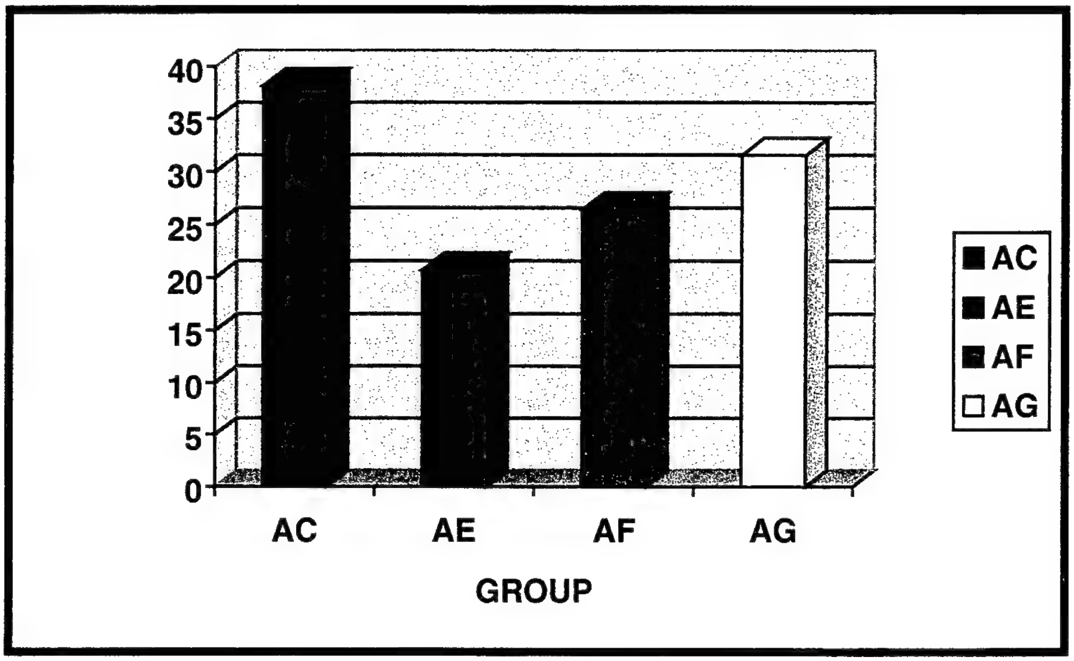

Figure 3-17. 4-year averaged performances on ANAMUKR: CDD-EFF.

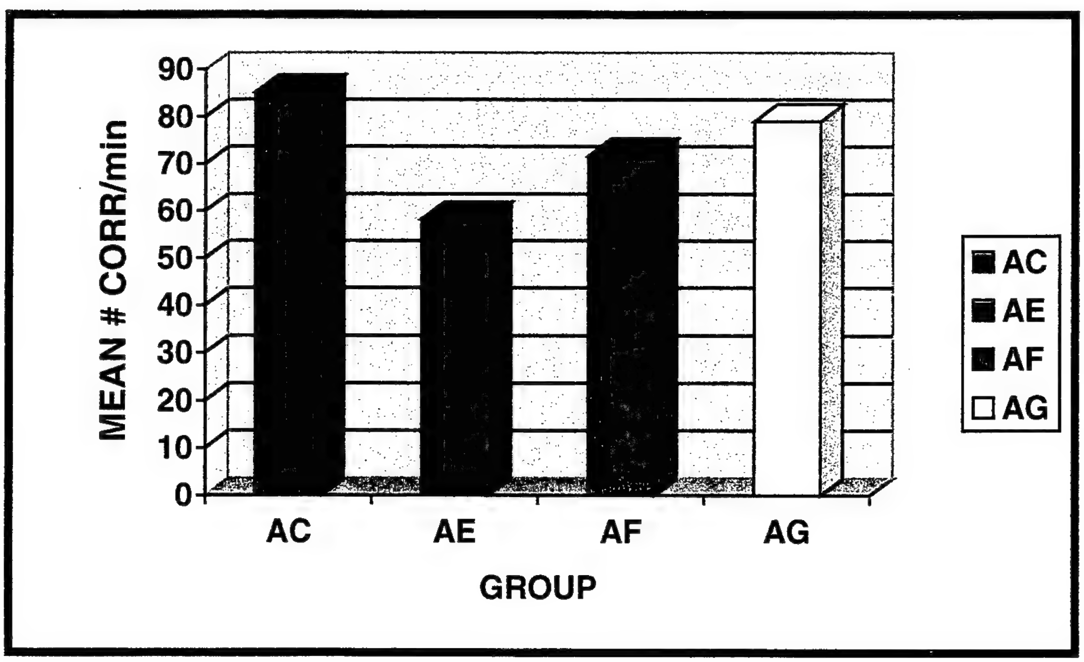

Figure 3-18. 4-year averaged performances on ANAMUKR: CPT-EFF.

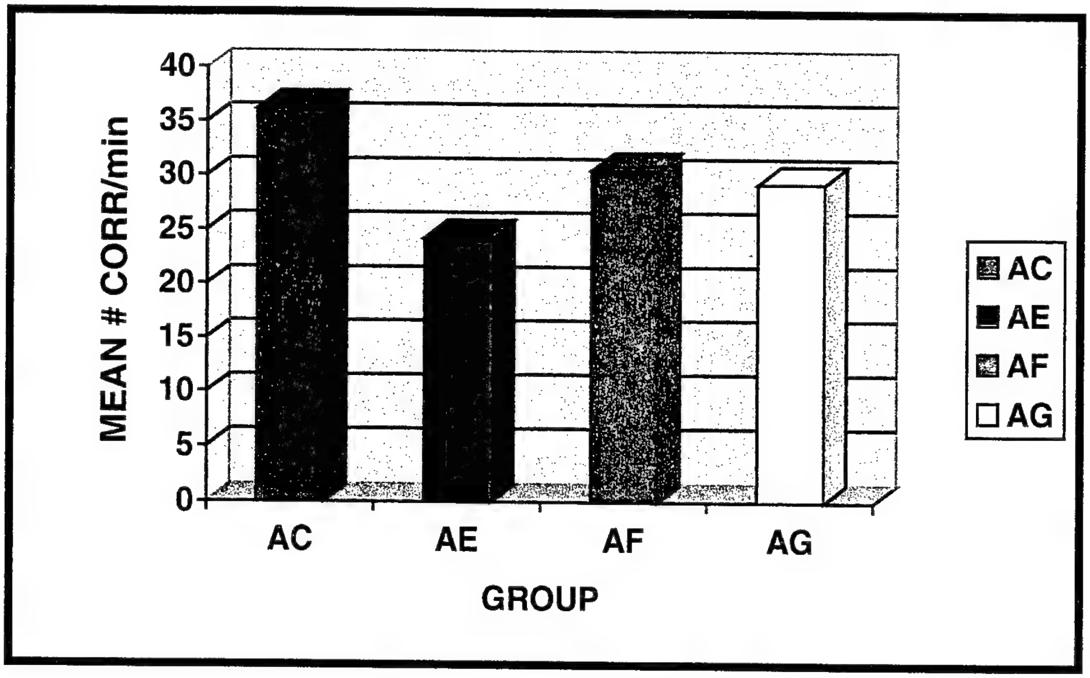

Figure 3-19. 4-year averaged performances on ANAMUKR: DGS-EFF.

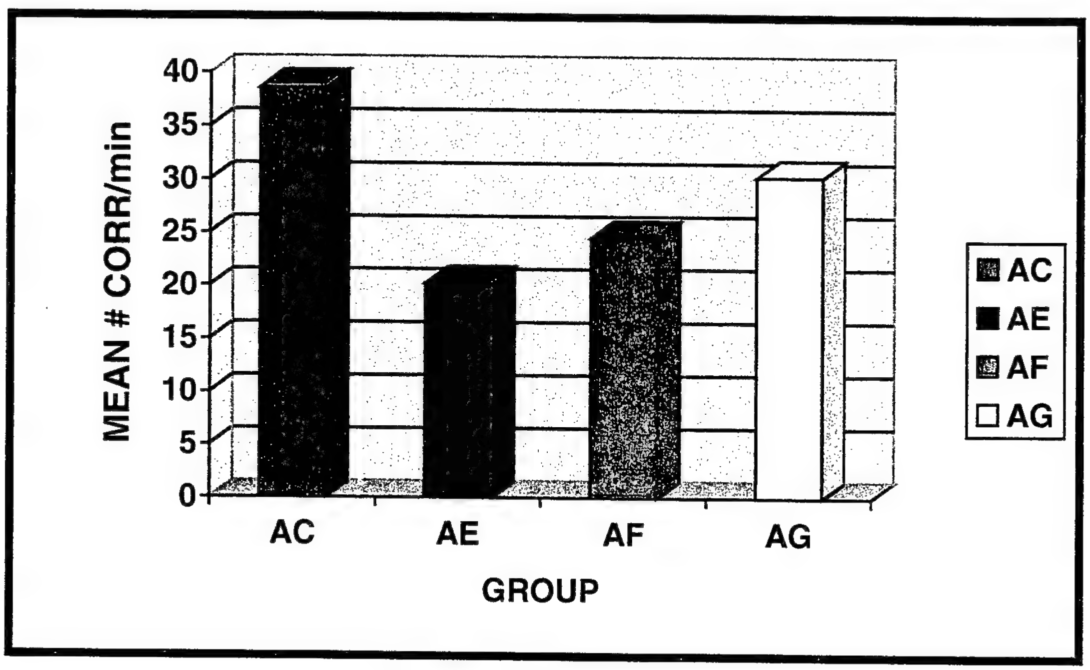

Figure 3-20. 4-year averaged performances on ANAMUKR: MSP-EFF.

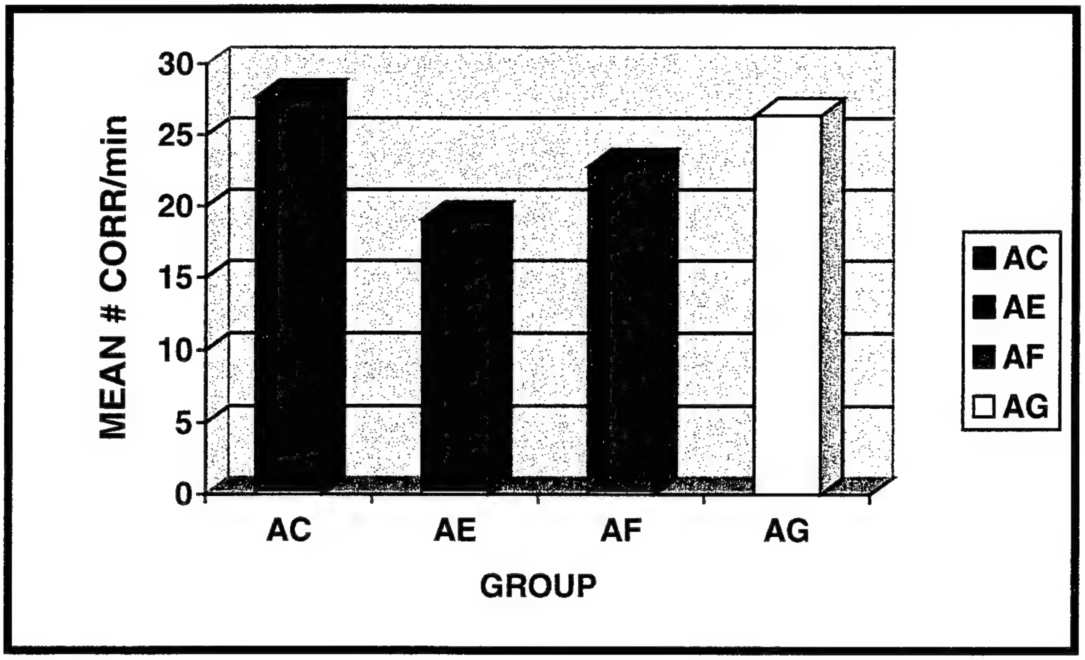

Figure 3-21. 4-year averaged performances on ANAMUKR: SPD-EFF.

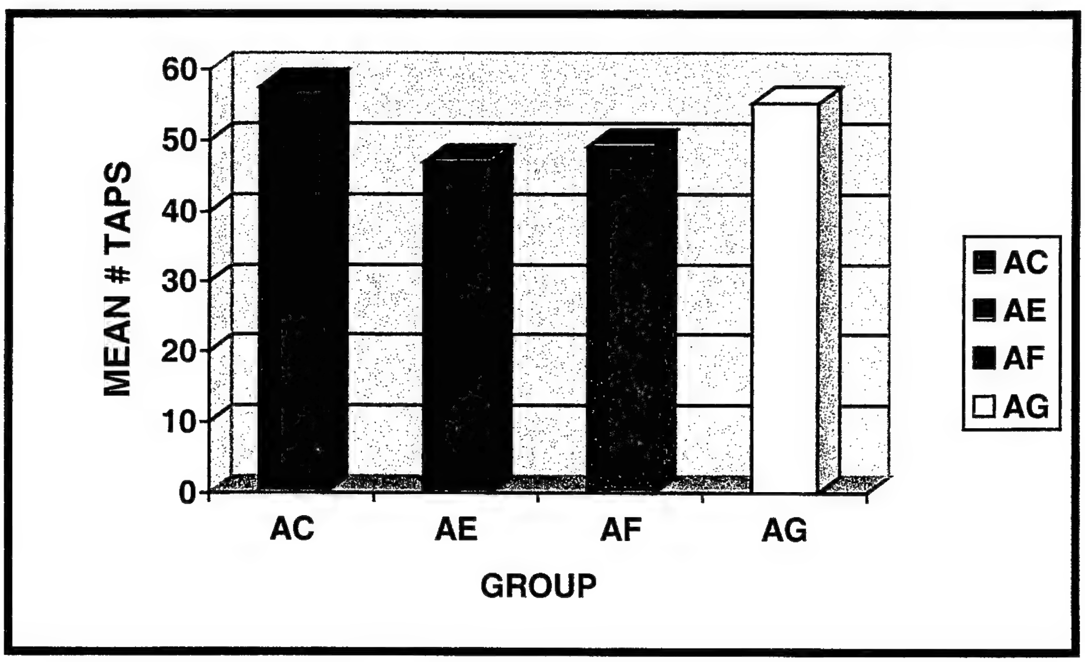

Figure 3-22. 4-year averaged performances on ANAMUKR: TAPPING-RIGHT.

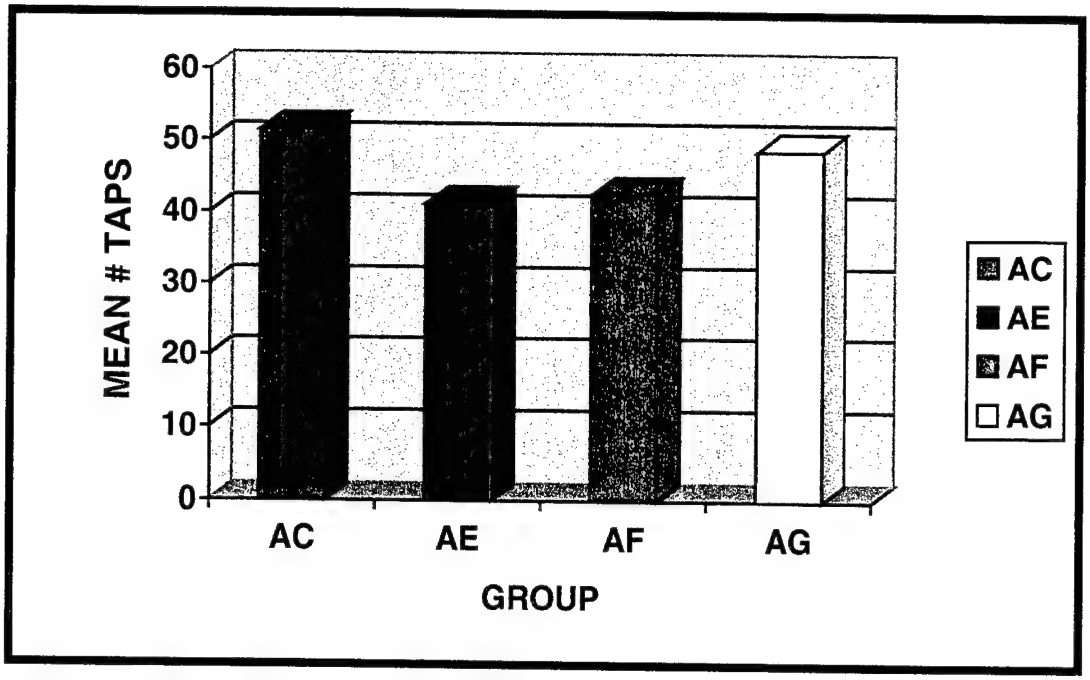

Figure 3-23. 4-year averaged performance on ANAMUKR: TAPPING LEFT.

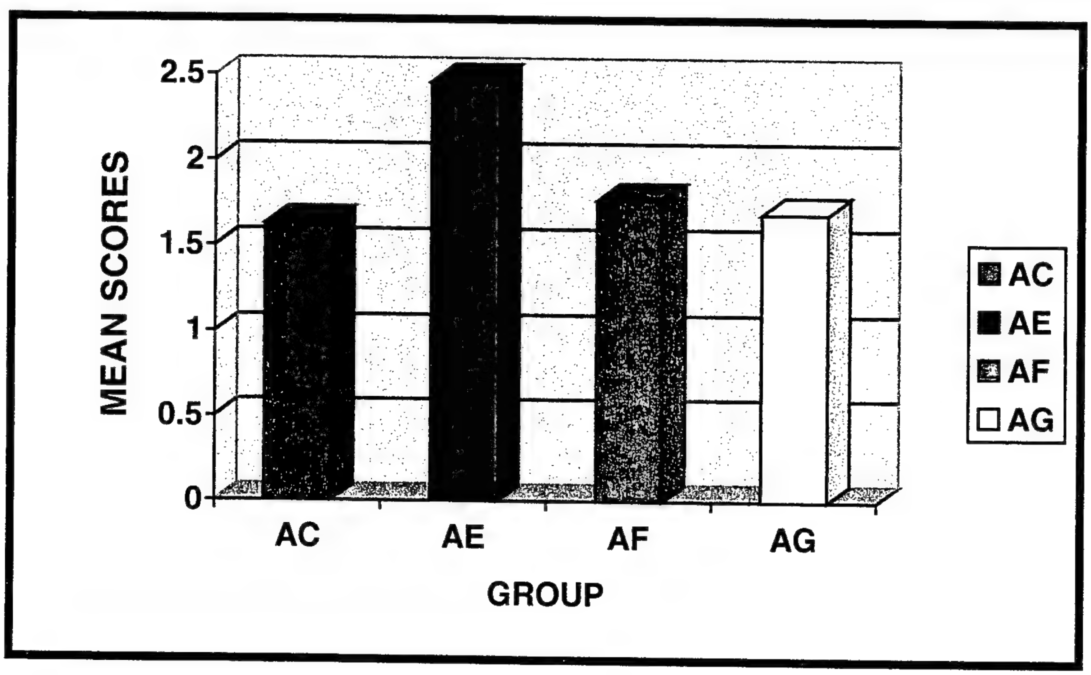

Figure 3-24. 4-year averaged scores on ANAMUKR: SLEEP SCALE.

3.3 RESULTS OF 1995 INITIAL TEST SESSION.

Because performance on the tasks within and among the test batteries is indexed in a variety of different ways, a measure was required which would describe comparisons between the exposure groups and the control group in similar terms across the tasks and test batteries. This measure consisted of determining the proportion of the control group's mean on a given task equivalent to an exposure group's mean on that task (i.e. mean-E / mean-C). The complement of this proportion (1-prop.) reflects the proportional difference between the means of the two groups on the task, and when multiplied by 100 it reflects the percent difference between the means of the two groups. The mean % difference for a given test battery was then calculated by obtaining the mean of the % differences for all the tasks in that battery. In all four cases the mean of a given exposure group on any given task was either equal to, or (most typically) less, than that of the control group. Therefore, the mean differences of all exposure groups on all test batteries reflected decrements in performance, as compared to the control group. Thus it seemed appropriate to describe the composite results of the 1995 test session in terms of mean % decrements as shown by the exposure groups relative to the control group, on all test batteries. These are presented in Table 3-6 and graphically in Figure 3-25.

Table 3-6. Mean % performance decrement for exposure groups relative to controls-1995.

GROUP	GPAB	ANAMUKR-ACC	ANAMUKR-EFF
AE	27.00	11.00	40.52
AF	16.88	7.35	23.91
AG	12.49	3.09	22.51

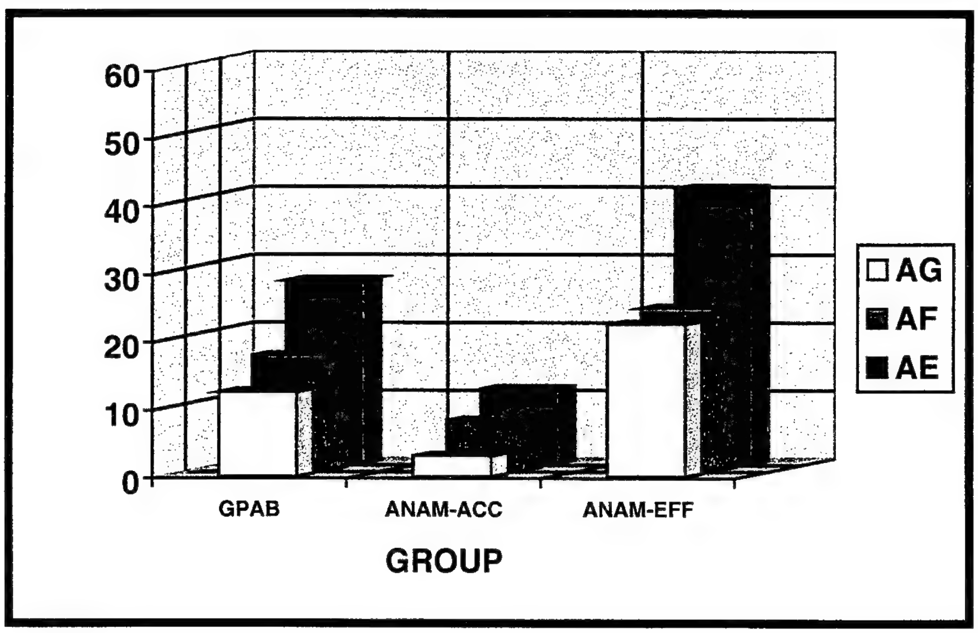

Figure 3-25. Mean % Decrement for Exposure Groups Relative to Controls-1995.

All of these decrements were significant, as evidenced by the results of multivariate analyses of variance (MANOVAs) described later. As dramatically illustrated in Figure 3- 25, the Eliminators were most drastically affected by their exposure to the radiation in the power station, on all test batteries. The other groups were also affected (although to a lesser degree) by the radiation in the Chernobyl region and showed sizeable decrements in performance on the test batteries as well.

3.3.1 GPAB.

Means and standard deviations for the groups on the GPAB are presented in Table 3-7.

Table 3-7. GPAB: 1995 Means (and standard deviations) for the four groups.

GROUP→ TASK	*AC*	*AE*	*AF*	*AG*
BROADJMP (meter)	1.57 (.18)	1.40 (.17)	1.39 (.16)	1.43 (.45)
CARRYWGT (meter)	43.42 (3.85)	36.61 (7.24)	37.17 (6.09)	40.58 (5.57)
SQUATTHR (number)	62.65 (10.01)	22.42 (8.78)	35.52 (12.72)	44.10 (17.39)
BALBEAM (meter)	19.61 (1.19)	16.22 (2.30)	19.93 (1.51)	18.65 (2.22)

The results of a MANOVA (Table 3-28) revealed a significant difference on the composite MEASURES. Univariate ANOVAs and *post-hoc* Dunnett tests, the results of which are presented in Tables 3-8 and 3-9, indicated that the ***AE***s were significantly impaired on *all 4* tasks as compared to the *AC*s. The ***AF***s were significantly lower than the ***AC***s on **BROADJMP**, **CARRYWGT** and **SQUATTHR**, while the ***AG***s were significantly lower on **SQUATTHR** only. Interestingly, the ***AF***s performed somewhat better than the ***AC***s on **BALBEAM;** this may well have resulted from their training in forestry work, including balancing on logs.

Table 3-8. GPAB: Results of MANOVA and univariate ANOVAS.

TASK	F	*p*<
COMP*	21.10	.001
BROADJMP	2.92	.05
CARRYWGT	9.33	.001
SQUATTHR	59.65	.001
BALBEAM	26.53	.001

Note: *Wilks' Lambda = .21

Table 3-9. GPAB: Groups significantly lower on physical abilities tasks than *AC*.

TASK	GROUP	*p*<
BRODJMP	*AE, AF*	.05, .05
CARRYWGT	*AE, AF*	.001, .001
SQUATTHR	*AE, AF, AG*	.001, .001, .001
BALBEAM	*AE*	.001

A discriminant function analysis, the results of which are presented in Table 3-10, indicated that the GPAB is extremely sensitive to the effects of exposure to ionizing radiation: 98.51% of ***AC***s and ***AE***s were correctly classified. Table 3-10 represents numbers of subjects.

Correlational analyses were performed for dosage of radiation and measures of physical performance for the ***AE***s. Significant negative correlations of rads with performance on **BRODJMP** and **SQUATTHR** (both ***r***s>-.35, ***p***s<.05) were revealed.

Table 3-10. GPAB: Results of discriminant function analysis for groups *AC* and *AE*.

ACTUAL GROUP	PREDICTED GROUP--*AC*	PREDICTED GROUP--*AE*
AC **(number)**	31	0
AE **(number)**	1	35

Subsequent analyses included comparisons of performance scores of females and males as a function of non-exposure or exposure to radiation. The control group included only 7 females; thus 7 males from this group were selected for comparison purposes. The 3 exposed groups included a total of 17 females, so 17 males (matching the numbers of females from each of these groups) were selected. Selection of males was not altogether random, since an attempt was made to ensure equivalence of ages between females and males. Means and standard deviations for the groups resulting from the combination of these variables are presented in Table 3-11, for each of the 4 physical tasks. The results of a MANOVA and univariate tests are presented in Table 3-12. MANOVA creates a composite measures based upon the corrolation relationship between individual measures.

Significant differences on the composite measures were revealed for the main effects of gender and exposure; however, the multivariate interaction was not significant. The univariate tests indicated that overall, males performed significantly better than females on **BRODJMP**, **CARRYWGT** and **SQUATTHR**, but not on **BALBEAM**. Further, the controls were significantly better than the exposed people on **SQUATTHR** and **BALBEAM**. None of the univariate interactions were significant, however, indicating that the magnitudes of the female-male differences did not differ as a function of exposure to radiation.

Table 3-11. GPAB: Means (and standard deviations) for females and males, either not exposed (controls) or exposed to radiation.

TASK	FEMALES-CONTROL	FEMALES-EXPOSED	MALES-CONTROL	MALES-EXPOSED
BROADJMP (meter)	1.36 (.11)	1.24 (.31)	1.72 (.13)	1.58 .37)
CARRYWGT (meter)	38.14 (2.04)	33.88 (6.38)	44.71 (3.25)	39.88 (7.27)
SQUATTHR (number)	46.86 (5.49)	36.41 (15.12)	66.29 (4.19)	44.82 (22.55)
BALBEAM (meter)	19.21 (.91)	17.19 (1.91)	20.21 (1.43)	18.44 (2.79)

Table 3-12. GPAB: MANOVA and univariate tests for females and males, either exposed or not exposed (controls) to radiation.

SOURCE	TASK	*F*	*p<*
FEMALE-MALE	COMP*	4.28	.01
	BRODJMP	13.42	.001
	CARRYWGT	5.05	.05
	SQUATTHR	7.00	.01
	BALBEAM	2.76	
CONTROL-EXPOSED	COMP**	3.34	.05
	BRODJMP	1.59	
	CARRYWGT	1.78	
	SQUATTHR	9.19	.01
	BALBEAM	7.85	.01
INTERACTION	COMP***	1.25	
	BRODJMP	.002	
	CARRYWGT	1.44	
	SQUATTHR	1.10	
	BALBEAM	.03	

Notes: * Wilks' Lambda = .71
** Wilks' Lambda = .75
*** Wilks' Lambda = .89

3.3.2 ANAMUKR: Accuracy.

Means and standard deviations of accuracy scores for the 9 ANAM tasks are presented in Table 3-13. Since all scores on **SRT** were 100%, this task was not included in data analyses. The results of a MANOVA revealed a significant difference on the composite measures. Univariate ANOVAs and *post-hoc* Dunnett tests indicated that these results were primarily due to the ***AE***s being significantly less accurate than the ***AC***s on 6 of the tasks: **CDS, CDI, CDD, CPT, DGS,** and **MSP**. These data indicate that the ***AE***s are experiencing remarkable decrements in short-term (working) memory, as 5 of these tasks assess integrity of this cognitive skill. The ***AF***s performed less accurately than the ***AC***s on 5 tasks: **2CH, CDI, CDD, DGS,** and **MSP**. Apparently, they are also experiencing some difficulties in short-term memory.

The ***AG***s were significantly less accurate on 2 tasks: **DGS** and **MSP**. Thus all the exposed groups are being affected by the ionizing radiation in varying degrees, as compared to the control group. The results of these analyses are presented in Tables 3-14 and 3-15.

Table 3-13. Accuracy (% Correct): 1995 Means (and Standard Deviations).

GROUP→ TASK	*AC*	*AE*	*AF*	*AG*
SRT	100.00 (0.00)	100.00 (0.00)	100.00 (0.00)	100.00 (0.00)
2CH	97.52 (3.51)	96.94 (3.19)	94.10 (7.05)	96.97 (2.83)
CDS	97.74 (1.84)	95.39 (3.77)	95.97 (3.55)	96.35 (3.05)
CDI	97.84 (4.10)	83.69 (15.48)	87.90 (8.33)	93.32 (6.67)
CDD	97.10 (3.42)	84.00 (16.84)	88.14 (9.23)	93.00 (7.75)
CPT	96.19 (4.29)	76.28 (15.72)	90.55 (8.28)	91.74 (5.56)
DGS	89.84 (8.52)	73.69 (13.46)	82.03 (11.28)	83.13 (7.96)
MSP	98.42 (2.98)	84.83 (10.64)	82.03 (11.28)	89.71 (15.18)
SPD	90.16 (5.24)	87.08 (8.97)	87.76 (8.41)	96.97 (2.83)

Table 3-14. Accuracy: Results of MANOVA and Univariate ANOVAs.

TASK	*F*	*p*<
COMP*	7.81	.001
2CH	3.67	.01
CDS	3.25	.05
CDI	12.74	.001
CDD	9.14	.001
CPT	26.03	.001
DGS	12.98	.001
MSP	13.35	.001
SPD	13.55	.001

Note: *Wilks' Lambda = .28

Table 3-15. Accuracy: Groups significantly less accurate than *AC*.

TASK	GROUP	*p*<
2CH	***AF***	.01
CDS	***AE***	.01
CDI	***AE, AF***	.001, .001
CDD	***AE, AF***	.001, .01
CPT	***AE***	.001
DGS	***AE, AF, AG***	.001, .05, .05
MSP	***AE, AF, AG***	.001, .001, .01
SPD	NONE	

The results of a discriminant function analysis for the *AC*s and *AE*s are presented in Table 3-16. The high percentage of correct classification (93%) is mainly a result of all the *AC*s being correctly classified, as only 14% of the *AE*s were misclassified. Nonetheless, accuracy of performance would appear to be a good indicator of the effects of the hazardous environment surrounding Chernobyl, and it is as sensitive to these effects as to those resulting from traumatic brain injury (Levinson & Reeves, 1997) and stroke (Goldstone et al. 1995).

Levels of exposure to varying dosages of radiation were obtained for each of the *AE*s. Mean dose was 62.95 (SD=32.64); these ranged from 18 rads to 144 rads. No significant correlations between rads dose and accuracy on any of the tasks were found.

Table 3-16. Accuracy: Results of discriminant function analysis for groups *AC* and *AE*.

ACTUAL GROUP	PREDICTED GROUP--*AC*	PREDICTED GROUP--*AE*
AC **(numbers)**	31	0
AE **(numbers)**	5	31

3.3.3 ANAMUKR: Efficiency.

Means and standard deviations of efficiency scores for the 9 ANAM tasks are presented in Table 3-17. Scores on **SRT** were included in these analyses. Once again, the results of a MANOVA (Table 38) revealed a significant difference on the composite measures. Univariate ANOVAs and ***post -hoc*** Dunnett tests, the results of which are presented in Tables 3-18 and 3-19, indicated that the ***AE***s were significantly impaired on ***all 9*** tasks as compared to the ***AC***s. These effects appear to be extremely profound: the mean response time on **SRT** was greater than that of a group of 70-year olds (Goldstone, et al. 1995); in fact, a discriminant function analysis, the results of which are presented in Table 3-20, resulted in over 91% correct classification of the ***AC***s and ***AE***s, with 34 of the 36 ***AE***s being correctly classified. The global impairment seen here is reminiscent of that observed in individuals who have suffered moderate traumatic brain injury (Levinson & Reeves, 1997). As with accuracy, the effects were not limited to the ***AE***s. The ***AF***s were significantly less efficient than the ***AC***s on 7 tasks: **SRT**, **CDS**, **CDI**, **CDD**, **CPT**, **DGS**, and **MSP**. The efficiency of the ***AG***s was similarly affected; they were significantly less efficient than the ***AC***s on 6 tasks: **CDS**, **CDI**, **CDD**, **CPT**, **DGS**, and **MSP**.

Since efficiency is partially based upon response speed, and since it was significantly lower for the ***AE***s on all tasks (and for the ***AF***s and ***AG***s on most of them), a MANCOVA was performed in which **SRT** was entered as a covariate. It was believed that adjusting for differences on this primarily motor measure would yield a clearer assessment of CNS-processing of information. Although a multiple regression analysis indicated that **SRT** was significantly correlated with the other measures combined (Multiple **R**=.72, p<.0001), the effect of adjusting for differences in **SRT** was slight (e.g., Wilks' Lambda increased from .28 to .33), and the overall picture emerging from the original MANOVA was not appreciably altered (see Table 3-18). These findings would appear to indicate that the observed differences in cognitive performance are reflective of impairments in information processing due to factors other than simple response speed.

Table 3-17. Efficiency (Correct responses/min): 1995 means (and standard deviations).

GROUP→ TASK	*AC*	*AE*	*AF*	*AG*
SRT	167.26 (46.34)	117.78 (43.14)	131.76 (47.05)	147.71 (48.24)
2CH	110.87 (25.49)	86.94 (27.06)	98.62 (32.97)	116.42 (19.63)
CDS	49.42 (14.44)	28.64 (8.74)	31.52 (18.69)	38.58 (13.95)
CDI	49.77 (15.39)	21.72 (8.44)	30.55 (17.67)	32.64 (12.13)
CDD	52.61 (13.04)	27.89 (10.94)	35.69 (19.85)	38.29 (10.81)
CPT	96.74 (19.68)	58.86 (16.88)	82.90 (22.63)	81.35 (18.53)
DGS	44.65 (10.45)	26.17 (8.07)	35.14 (10.11)	29.94 (8.06)
MSP	51.55 (16.77)	26.39 (10.49)	32.59 (19.14)	29.29 (11.20)
SPD	32.61 (9.85)	20.33 (6.05)	32.14 (11.88)	26.03 (7.27)

Table 3-18. Efficiency: Results of MANOVA and univariate ANOVAs (and MANCOVA and univariate ANCOVAs with SRT as a covariate).

TASK	F	*p*<
COMP*	6.79 (6.51)	.001 (.001)
SRT	7.00	.001
2CH	8.15 (4.58)	.001 (.01)
CDS	13.77 (6.55)	.001 (.001)
CDI	24.27 (16.14)	.001 (.001)
CDD	17.98 (11.29)	.001 (.001)
CPT	22.14 (14.77)	.001 (.001)
DGS	24.75 (18.46)	.001 (.001)
MSP	19.20 (13.55)	.001 (.001)
SPD	14.11 (11.42)	.001 (.001)

Notes: *Wilks' Lambda = .28 (.33)

Table 3-19. Efficiency: Groups significantly less efficient than *AC*.

TASK	GROUP	*p*<
SRT	*AE*, *AF*	.001, .01
2CH	*AE*	.001
CDS	*AE*, *AF*, *AG*	.001, .001, .01
CDI	*AE*, *AF*, *AG*	.001, .001, .001
CDD	*AE*, *AF*, *AG*	.001, .001, .001
CPT	*AE*, *AF*, *AG*	.001, .01, .01
DGS	*AE*, *AF*, *AG*	.001, .001, .001
MSP	*AE*, *AF*, *AG*	.001, .001, .001
SPD	*AE*, *AG*	.001, .01

Table 3-20. Efficiency: Results of discriminate function analysis for groups *AC* and *AE*.

ACTUAL GROUP	PREDICTED GROUP--*AC*	PREDICTED GROUP--*AE*
AC (numbers)	27	4
AE (numbers)	2	34

Correlational analyses were also performed for dose of radiation and efficiency of performance for the *AE*s. Unlike accuracy, significant negative correlations of rads dose with efficiency on **CDI, CDS, CPT, DGS,** and **MSP** (all of which assess short-term memory), as well as with **SRT** (all *r*s>-.36, all *p*s<.05) were revealed.

3.3.4 ANAMUKR*:* Additional Measures.

Means and standard deviations for the groups on **TAPR, TAPL,** and **SLP** are shown in Table 3-21.

Table 3-21. ANAMUKR additional measures: Means (and standard deviations).

GROUP → TASK	*AC*	*AE*	*AF*	*AG*
TAP-R (mean n of responses in 10 sec.)	54.26 (11.48)	41.31 (14.37)*	45.90 (13.05)*	49.87 (12.27)
TAP-L (mean n of responses in 10 sec.)	47.44 (9.85)	37.26 (12.15)*	40.30 (11.93)*	46.97 (9.33)
SLP (scores from 1-7)	1.84 (1.29)	2.88 (1.45)*	2.29 (.70)	2.63 (1.17)

Note: *significantly different than controls

Differences among the groups were significant on all of these measures (*F*s > 4.36, *p*s < .01). Compared to the ***AC***s, tapping rates for both hands were significantly lower for the ***AE***s (.001) and for the ***AF***s (.05); while levels of sleepiness were higher for the ***AE***s (.001).

3.3.5 GPAB-ANAMUKR*:* Correlational Analyses.

Significant correlations were found between many of the measures on the GPAB; these are presented in Table 3-22, along with intercorrelations between performance on the tasks comprising the GPAB and accuracy of performance on the tasks in ANAMUKR for the combined groups (N=127).

Table 3-22. **Pearson correlations between GPAB and ANAMUKR: Accuracy (N=127).**

TASK	BRODJMP	CARRY WGT	SQUATTHR	BALBEAM
BRODJMP				
CARRYWGT	.59**			
SQUATTHR	.62**	.65**		
BALBEAM	-.04	.14	.30**	
CDD	.01	.11	.27**	.19*
CDI	.14	.32**	.37**	.17
CDS	.02	.06	.11	.21*
CPT	.18	.21*	.48**	.45**
DGS	.15	.14	.37**	.26**
MSP	.29**	.31**	.41**	.05
SPD	-.06	.11	.08	.14
SRT	.03	-.08	.06	.09
2CH	-.07	-.02	-.05	- .01

Notes: * $p<.05$
** $p<.01$

As indicated above, **SQUATTHR** was significantly and positively correlated with all other physical tasks, and with accuracy of performance on cognitive tasks involving working memory. Further, **BALBEAM** was significantly and positively correlated with accuracy on **CPT**; both of these tasks require sustained attention.

Similar Pearson correlations were calculated for each separate group. Because of the reductions in sample size, many of the significant correlations observed for the combined groups were lost. Nonetheless, a few interesting ones remained. For the ***AC*s**, **CARRYWGT** and **SQUATTHR** were correlated with **CDS** and **CDI**; while for the ***AE*s** and ***AG*s**, **BALBEAM** was correlated with **CPT**.

The intercorrelations between performance on the tasks in the GPAB and efficiency of performance on the tasks in ANAMUKR are presented in Table 3-23. Compared to accuracy, many more significant correlations were observed between ANAMUKR efficiency and physical performance. Especially noteworthy is the finding that **SQUATTHR** was significantly and positively correlated with *all* cognitive tasks. In addition **BALBEAM** was significantly and positively correlated with many of the cognitive tasks requiring sustained attention and working memory (e.g., **CPT**, **CDI**, and **CDD**).

As was the case with the correlations between cognitive accuracy and physical performance, much of the significance of the correlations between cognitive efficiency and physical performance was lost when they were calculated for the individual groups. However, several interesting significant correlations remained, including **BALBEAM-CPT** for the ***AE*s**, and **SQUATTHR** and several tasks for the ***AG*s**.

Table 3-23. Pearson correlations between GPAB and ANAMUKR: Efficiency (N=127).

TASK	BRODJMP	CARRYWGT	SQUATTHR	BALBEAM
CDD	.04	.07	.42**	.26**
CDI	.21*	.20*	.54**	.24**
CDS	.23*	.19*	.45**	.16
CPT	.28**	.19*	.49**	.40**
DGS	.24**	.23**	.48**	.27**
MSP	.27**	.29**	.49**	.22*
SPD	.16	.15	.31**	.36**
SRT	.35**	.21*	.48**	.13
2CH	.10	.11	.24**	.23*

Notes: * $p<.05$
** $p<.01$

Table 3-24 presents the correlation between the GPAB tasks and the other ANAMUKR measures.

Table 3-24. Pearson correlations between GPAB and ANAMUKR: Additional measures (N=127).

TASK	BRODJMP	CARRYWGT	SQUATTHR	BALBEAM
TAP-R	.06	.13	.27**	.24**
TAP-L	.20*	.18*	.27**	.20**
SLP	- .24**	-.23*	-.37**	-.15

Notes: * $p<.05$
** $p<.01$

Since the tapping task measures fine motor coordination, it is not surprising that it is primarily correlated with **SQUATTHR** (a measure of dynamic strength) and **BALBEAM** (a measure of balance). Further, the correlations between tapping and balance may be reflective of cerebellar function. The finding that the ***AE***s are significantly impaired on these tasks relative to the ***AC***s might therefore indicate that the integrity of their cerebellar (as well as cerebral) function has been damaged by exposure to adionuclides. The negative correlations between **SLP** and the 3 **GPAB** tasks requiring strength would appear to at least indirectly support the validity of the sleep scale.

3.3.5.1 Age. Since ages of all 127 participants were obtained, correlations between it and all other variables were calculated. Significant negative correlations were observed between age and three of the GPAB tasks (**BRODJMP**, **CARRYWGT**, and **SQUATTHR**: all rs>.36, all ps<.01); in contrast, a significant positive correlation was revealed between age and **BALBEAM** (r=.24, p<.01). Significant negative correlations (rs>.20, ps<.05) were observed for accuracy on two ANAMUKR tasks (**CDI**, **MSP**), and for efficiency on five tasks (**CDS**, **CDI**, **CDD**, **MSP**, and **SRT**). Most of these are attention-memory tasks. These data are in concert with other studies relating age and cognitive performance (e.g., Goldstone, et. al, 1995).

3.4 RESULTS OF 1996 RETEST SESSION.

Two Eliminators and one Forestry worker were not available for the retest session, and therefore their 1995 data could not be included in the analyses of the retest results. The remaining Ns of the exposure groups were Eliminators-34, Forestry workers-28, and Agricultural workers-31. The Control group (AC) were tested in 1995, 1996, 1997 and 1998. There were no meaningful differences among these testings. It was decided to use the 1995 Control group as a comparison for all subsequent experimental groups.

3.5 GLOBAL ASSESSMENTS OF DECLINES BY EXPOSURE GROUPS.

Mean percent decrements in performance for the exposure groups on the 1996 retest relative to the 1995 Control data are presented in Table 3-25 and graphically illustrated in Figure 3-16.

Table 3-25. Mean % performance decrement for exp. groups-1996 relative to controls-1995.

GROUP	GPAB	ANAMUKR-ACC	ANAMUKR-EFF
AE	33.73	12.78	47.16
AF	16.38	10.11	35.42
AG	11.85	6.23	30.36

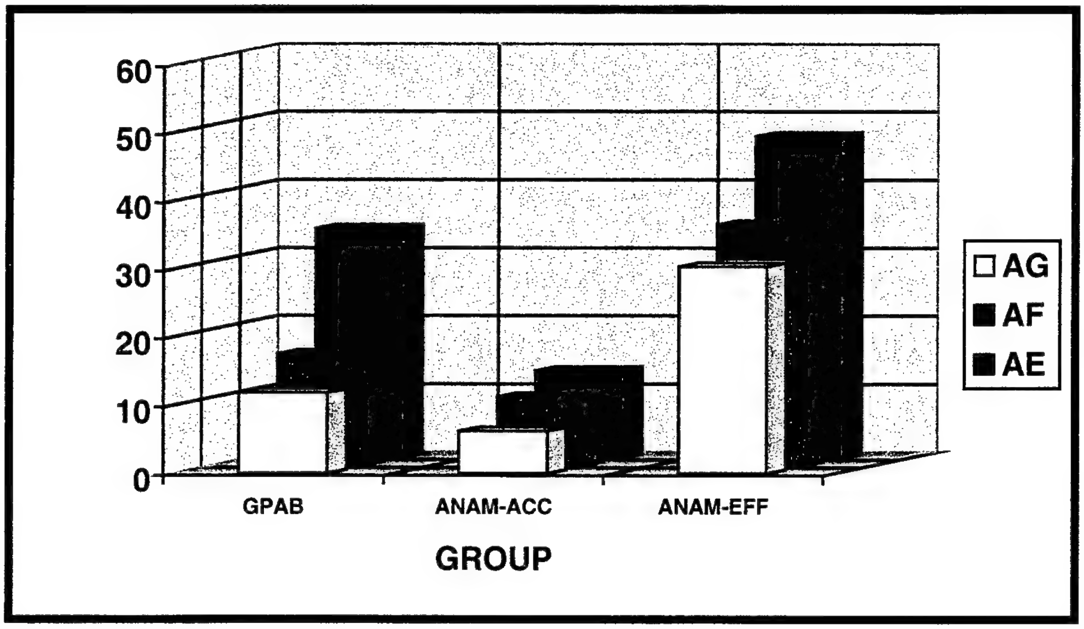

Figure 3-26. Mean % Decrement for Exposure Groups-1996 Relative to Controls-1995.

The data of Figure 3-26 are similar to those illustrated in Figure 3-25; however, except for Groups ***AF*** and ***AG*** on the GPAB, the magnitude of the 1996 differences between the exposure groups and the Controls is noticeably greater than those of 1995. In addition to declines in performance in groups significantly lower than the Controls in 1995, the performance of several groups not significantly lower than the Controls on certain tasks in 1995 declined to significant levels in 1996; these are listed in Table 3-46.

Using a procedure similar to that for calculating mean percent decrement of the exposure groups relative to the Controls, the mean percent declines for each of these groups on each battery of tests were calculated by using 1995 levels of performance as a baseline by which to gauge 1996 levels (i.e., mean - 1996 / mean-1995). These declines are presented in Table 3-27 and illustrated graphically in Figure 3-27. With the exception of Groups ***AF*** and ***AG*** on the GPAB, all groups showed significant declines as revealed by MANOVAs, the results of which are presented in Table 3-28, on all test batteries from 1995 to 1996. These findings indicate that both the physical (in the case of Group ***AE***) and cognitive performance levels in these groups of individuals are worsening over time.

Table 3-26. Groups not Significantly Lower than *AC* in 1995, but significantly lower in 1996.

BATTERY: TASK	GROUP	$p<$
GPAB		
BRODJUMP	*AE*	.001
ANAM-ACCURACY		
2CH	*AE, AG*	.01, .01
CDS	*AF*	.01
CDI	*AG*	.001
CDD	*AG*	.001
SPD	*AE, AF*	.001, .01
ANAM-EFFICIENCY		
SPD	*AF*	.001

Table 3-27. Mean % Performance Decline for Exposure Groups: 1995-1996.

GROUP	GPAB	ANAMUKR-ACC	ANAMUKR-EFF
AE	9.78	1.95	11.89
AF	0.00	2.84	15.22
AG	0.00	3.18	9.03

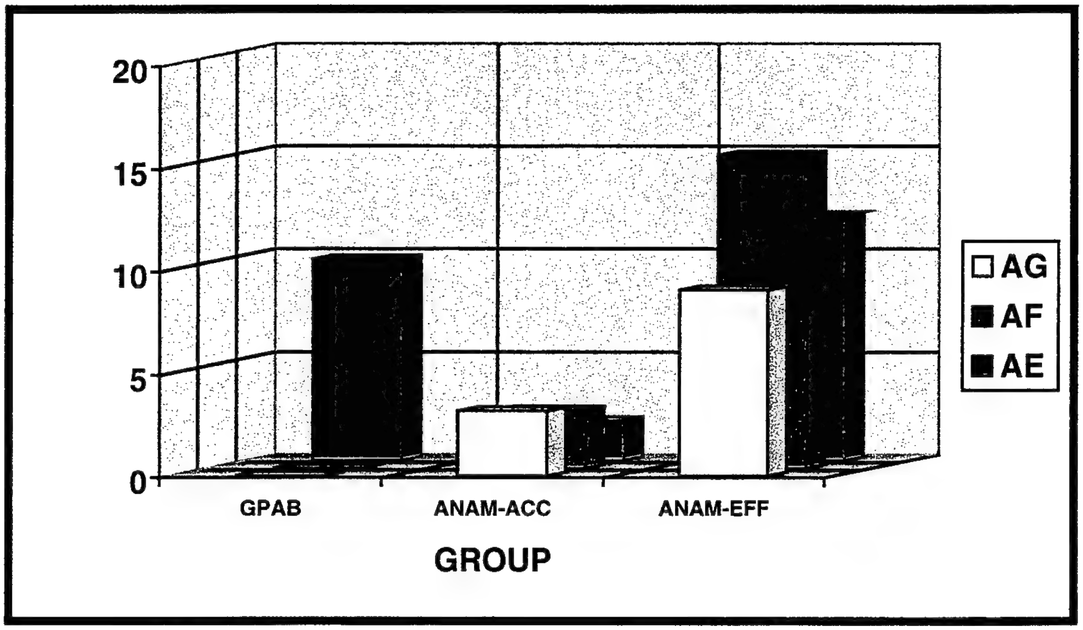

Figure 3-27. Mean % decline for exposure groups: 1995-1996.

Table 3-28. Significant multivariate declines by exposure groups.

TEST BATTERY	GROUP	WILKS' LAMBDA	F	*p*<
GPAB	***AE***	.39	11.95	.001
ANAM-ACC	***AE***	.51	3.07	.01
	AF	.42	3.49	.01
	AG	.38	4.60	.01
ANAM-EFF	***AE***	.39	4.39	.001
	AF	.28	5.01	.001
	AG	.32	5.32	.001

3.6 SPECIFIC ASSESSMENTS OF DECLINES IN EXPOSURE GROUPS.

Means and standard deviations for the exposure groups on the 1996 GPAB retest are presented in Table 3-29. Similar data for accuracy, efficiency, and the additional measures performance on the 1996 ANAMUKR retest are presented in Tables 3-30, through 3-32, respectively. Significant declines, as revealed by the results of univariate analyses comparing the 1996 levels of performance of the exposure groups on the various tasks in the test batteries to their 1995 levels, are presented in Table 3-33, along with the figure number from Figures 3-30 through 3-53 illustrating these declines.

3.6.1 GPAB.

Already significantly weaker than the ***AC***s (1995), the ***AE***s continued to decline on all measures of strength, including explosive, static and dynamic. These findings indicate that they are physically deteriorating, even 10 years following their exposure to the radiation in the power station. In contrast, the ***AF***s and ***AG***s maintained their 1995 levels--perhaps because they are working in occupations requiring physical exertion and were therefore able to "stay in shape".

TABLE 3-29. GPAB: 1996 means (and standard deviations) for the exposure groups.

TASK	***AE***		***AF***		***AG***	
BRODJMP	1.30	(.28)	1.37	(.14)	1.41	(.42)
CARRYWGT	30.56	(11.68)	38.89	(5.93)	41.48	(6.03)
SQUATTHR	19.47	(7.44)	35.39	(11.97)	43.74	(17.07)
BALBEAM	15.85	(3.16)	20.02	(1.76)	19.11	(1.20)

3.6.2 ANAMUKR: Accuracy.

All three exposure groups showed significant declines in accuracy of performance on a variety of the tasks. Most of these declines occurred in Groups ***AF*** and ***AG***, on tasks assessing both attention and memory skills. Nonetheless, the ***AE***s declined as well, on tasks requiring sustained attention. Surprisingly, all three groups showed significant declines on **SPD**, indicating a developing difficulty in skills related to assessment of spatial relations.

Table 3-30. ANAMUKR Accuracy (% correct): 1996 means (and standard deviations) for the exposure groups.

TASK	*AE*		*AF*		*AG*	
SRT	100.00	(.00)	100.00	(.00)	100.00	(.00)
2CH	94.26	(5.30)	94.79	(4.53)	93.90	(7.19)
CDS	93.59	(3.66)	94.07	(3.21)	95.39	(3.32)
CDI	79.85	(8.07)	82.96	(8.54)	88.71	(10.55)
CDD	79.53	(9.96)	81.11	(6.79)	84.00	(10.75)
CPT	83.24	(16.15)	89.11	(6.96)	91.61	(6.80)
DGS	74.82	(10.26)	83.43	(7.03)	85.16	(8.56)
MSP	80.94	(13.30)	81.18	(16.88)	89.58	(9.14)
SPD	80.88	(7.83)	81.79	(6.56)	88.55	(6.73)

3.6.3 ANAMUKR: Efficiency.

As with accuracy, all exposure groups exhibited significant declines in efficiency of performance on the majority of the tasks. Most of these were the same tasks upon which their accuracy declined. Thus the declines in efficiency are not surprising, since efficiency is based in part on accuracy of performance. Nonetheless, it should be noted that none of the groups showed significant declines in **SRT**, and therefore the declines in efficiency cannot be explained by slowing of response speed (the other factor upon which efficiency of performance is based). The finding that declines in efficiency for the most part accompanied corresponding declines in accuracy would indicate that these individuals are experiencing difficulty in processing cognitive information on tasks entailing attention, memory and spatial abilities.

Table 3-31. ANAMUKR Efficiency (correct responses/min): 1996 means (and standard deviations) for the exposure groups.

TASK	*AE*	*AF*	*AG*
SRT	117.74 (34.16)	136.93 (52.23)	139.00 (52.65)
2CH	76.47 (29.60)	90.39 (31.89)	98.13 (33.56)
CDS	23.35 (8.03)	31.79 (21.41)	30.45 (11.55)
CDI	17.35 (5.71)	27.57 (16.19)	26.29 (11.48)
CDD	20.74 (8.47)	25.50 (13.26)	29.13 (12.77)
CPT	61.26 (18.08)	74.14 (24.49)	79.74 (27.67)
DGS	25.26 (7.57)	29.39 (7.48)	30.87 (10.87)
MSP	19.82 (8.52)	21.82 (11.30)	31.81 (15.30)
SPD	18.41 (7.22)	21.18 (9.29)	24.97 (9.53)

3.6.4 ANAMUKR: Additional Measures.

Means and standard deviations for the exposure groups are shown in Table 3-32.

Table 3-32. ANAMUKR Additional measures: 1996 means (and standard deviations).

TASK	*AE*	*AF*	*AG*
TAP-R (mean n of responses in 10 sec)	42.82 (9.74)	48.351 (11.38)	55.58 (13.37)
TAP-L (mean n of responses in 10 sec)	37.97 (8.11)	41.00 (10.04)	49.30 (12.07)
SLP (scores from 1-7)	2.59 (.71)	1.27 (.46)	1.46 (.59)

No significant changes were observed from 1995 to 1996 in rates of tapping for either hand by any group; however, all 3 groups showed significant decreases in levels of sleepiness (all Fs > 4.29, all ps < .05).

Table 3-33 shows the significant declines in performance from 1995 to 1996 for the GPAB tasks, and for accuracy and efficiency on ANAMUKR; the figure number refers to the figure which specifically illustrates the decline.

Table 3-33. Significant declines in performance by the exposure groups: 1995 to 1996.

BATTERY: TASK	GROUP	F	*p*<	FIG. #
GPAB				
BRODJUMP	***AE***	8.29	.01	30
CARRYING WGT	***AE***	31.58	.001	31
SQUATTHRUSTS	***AE***	16.32	.001	32
ANAM-ACCURACY				
2CH	***AE, AG***	7.90, 4.37	.01, .05	34
CDS	***AE, AF***	5.71, 7.90	.05, .01	35
CDI	***AF, AG***	5.52, 5.52	.05, .05	36
CDD	***AF, AG***	10.30, 12.53	.01, .001	37
SPD	***AE, AF, AG***	10.05, 12.04, 35.40	.01, .01, 001	41
ANAM-EFFICIENCY				
2CH	***AG***	7.45	.01	43
CDS	***AE, AG***	8.01, 10.96	.01, .01	44
CDI	***AE, AG***	6.15, 7.90	.01, .01	45
CDD	***AE, AF, AG***	11.02, 4.62, 10.89	.01, .05, .01	46
DGS	***AF***	7.51	.01	48
MSP	***AE, AF***	10.30, 8.01	.01, .01	49
SPD	***AF***	14.67	.001	50

3.7 RESULTS OF 1997 RETEST SESSION.

Because of unavailability for testing resulting from relocation, illness, or death, 1997 data were obtained on 34 Eliminators, 20 Forestry workers, and 28 Agricultural workers. However, some of these had not been available for testing on the GPAB and/or ANAMUKR in 1996, so the 1996-97 comparisons were based on Ns as follows: GPAB—Eliminators-32, Forestry workers-18, Agricultural workers-28; ANAMUKR—Eliminators-30, Forestry workers-15, Agricultural workers-28. Because many of the original forestry workers were unavailable for testing in 1997, a new group of 13 foresters was tested. However, since this was their first year of testing, their data could not be included in the analyses.

3.7.1 Global Assessments of Declines By Exposure Groups.

Mean percent decrements in performance for the exposure groups on the 1997 retest relative to the 1995 control data are presented in Table 3-34 and graphically illustrated in Figure 3-28. The data of Figure 3-28 are similar to those illustrated in Figures 3-25 and 3-26, except that decrements in ANAMUKR accuracy for Groups ***AE*** and ***AF*** are more pronounced.

Table 3-34. Mean % performance decrement for exp. groups-1997 relative to controls-1995.

GROUP	GPAB	ANAMUKR-ACC	ANAMUKR-EFF
AE	35.97	23.24	50.54
AF	9.93	14.96	43.68
AG	11.60	8.46	34.57

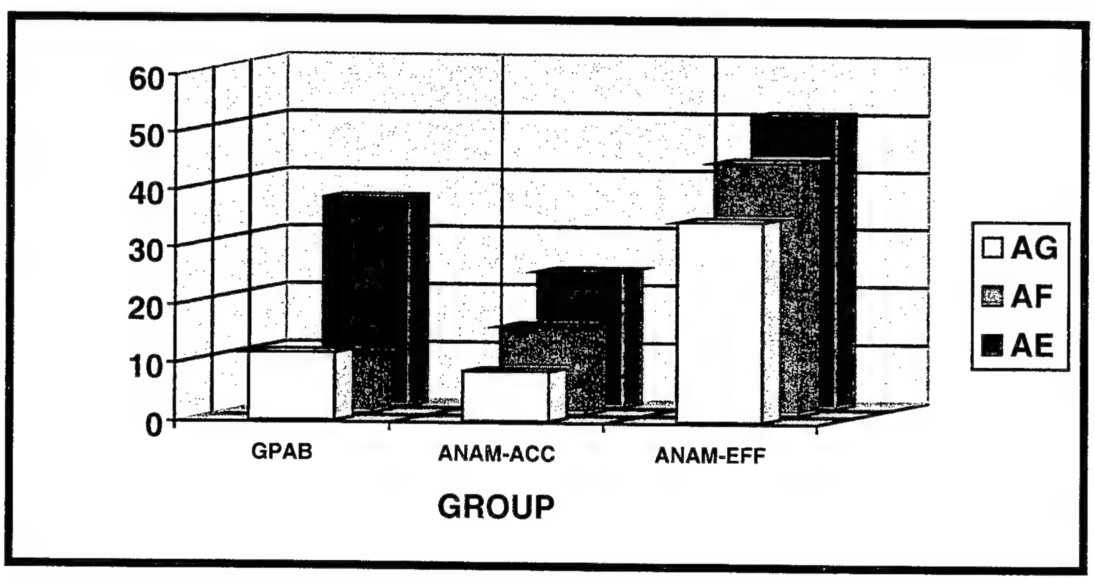

Figure 3-28. Mean % decrement for exposure groups-1997 relative to controls-1995.

In addition to continuing declines exhibited by all the groups on at least some of the measures, the performance of Groups ***AF*** and ***AG*** not significantly lower than that of the Controls in 1995 or 1996 declined to significant levels on several tasks in 1997. These are listed in Table 3-35.

Table 3-35. Groups not significantly lower than *AC* in 1995 or 1996, but significantly lower in 1997.

BATTERY: TASK	GROUP	$p<$
GPAB		
BALANCE BEAM	***AF***	.05
ANAM-ACCURACY		
CDS	***AG***	.05
CPT	***AF***	.001
ANAM-EFFICIENCY		
SRT	***AG***	.01
2CH	***AF, AG***	.001, .05

Using a procedure similar to that for calculating mean percent decrement of the exposure groups relative to the Controls, the mean percent declines for each of these groups on each battery of tests were calculated by using 1995 levels of performance as a baseline by which to gauge 1997 levels (i.e., mean - 1997 / mean-1995). These declines are presented in Table 3-36 and illustrated graphically in Figure 3-29. With the exception of Groups ***AF*** and ***AG*** on the GPAB, all groups showed significant declines as revealed by MANOVAs, the results of which are presented in Table 3-37, on all test batteries from 1995 to 1997. These findings indicate that both the physical (in the case of Group ***AE***) and cognitive performance levels in these groups of individuals are worsening over time.

Mean percent declines in performance by the 3 exposure groups from 1996 to 1997 are presented in Table 3-36 and graphically illustrated in Figure 3- 29. As revealed by MANOVAs, the decline of Group ***AE*** on the GPAB was significant, as were those of all 3 groups on ANAM accuracy. The declines in ANAM efficiency, although noteworthy, were not significant.

Table 3-36. Mean % performance decline for exposure groups: 1996-1997.

GROUP	GPAB	ANAMUKR-ACC	ANAMUKR-EFF
AE	3.00	12.43	5.20
AF	0.00	8.44	14.52
AG	0.00	2.43	6.41

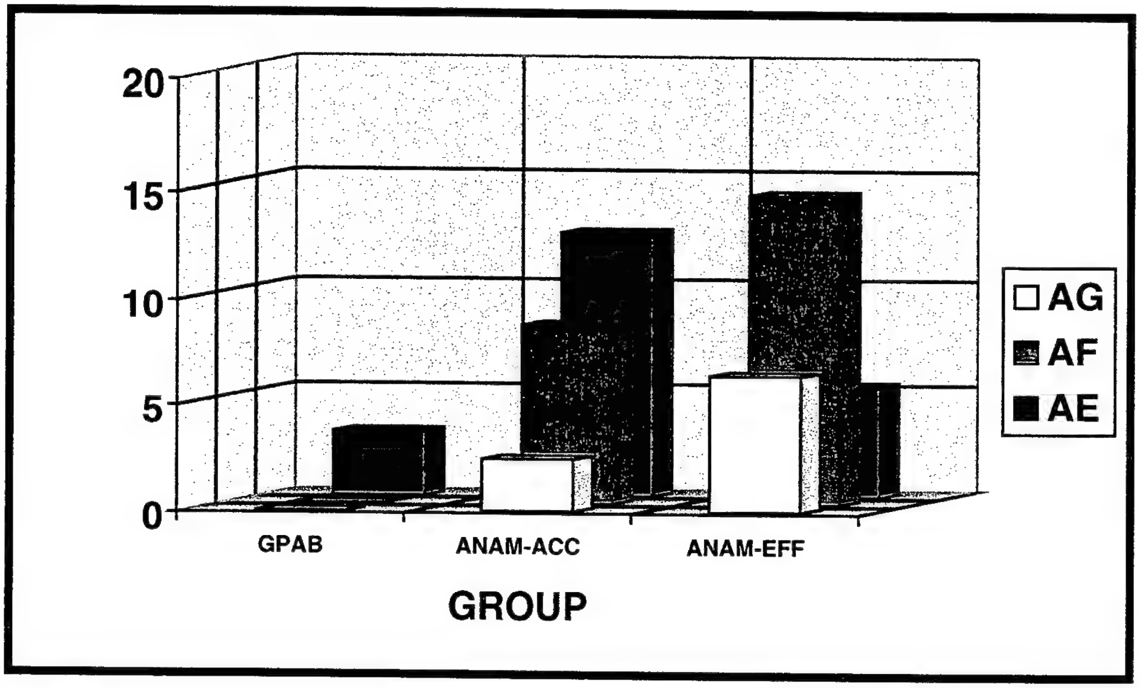

Figure 3-29. Mean % Decline for Exposure Groups: 1996-1997.

These findings indicate that the physical performance of Group ***AE*** and the accuracy of performance of all 3 exposed groups are continuing to significantly decline. Although a MANOVA indicated that the decline of Group ***AE*** on efficiency was also significant, a MANCOVA using **SRT** as a covariate revealed that the significance was a result of slowing of reaction time only (see Table 3-41). The results of the MANOVAs assessing the significance of the changes in performance for all 3 groups from 1996 to 1997 are presented in Table 3-37.

Table 3-37. Significant multivariate declines by exposure groups from 1996 to 1997.

TEST BATTERY	GROUP	WILK'S LAMBDA	F	*p*<
GPAB	*AE*	.52	6.48	.001
ANAM-ACC	*AE* *AF* *AG*	.14 .09 .47	17.31 8.62 2.84	.001 .01 .05
ANAM-EFF	*AE*	.39	3.63	.01*

Note: *n.s. when analyzed via MANCOVA using SRT as a covariate.

3.7.2 Specific Assessments of Declines in Exposure Groups.

Means and standard deviations for the exposure groups on the 1997 GPAB retest are presented in Table 3-38. Similar data for accuracy and efficiency of performance on the 1997 ANAMUKR retest, and for the additional ANAMUKR measures, are presented in Tables 3-39, through 3-41 respectively. Figures 3-30 through 3-53 illustrate changes in performance for the three exposure groups from 1996 to 1997 (as well as from 1995-1996). On each figure, the 1995 control data are again included as a point of reference. Significant declines, as revealed by the results of univariate analyses comparing the 1997 levels of the exposure groups on the various tasks in the test batteries to their 1996 levels, are presented in Table 3-42 along with the figure number from Figures 3-30 through 3-53 illustrating these declines.

Table 3-38. GPAB: 1997 means (and standard deviations) for the exposure groups.

TASK	*AE*		*AF*		*AG*	
BRODJMP (meter)	1.24	(.28)	1.42	(.20)	1.40	(.44)
CARRYWGT (meter)	28.32	(12.13)	42.05	(7.99)	41.00	(6.77)
SQUATTHR (number)	19.71	(8.39)	41.65	(13.81)	45.04	(19.30)
BALBEAM (meter)	15.76	(2.55)	20.95	(1.94)	19.25	(1.85)

Table 3-39. **ANAMUKR: Accuracy (% correct): 1997 means (and standard deviations) for the exposure groups.**

TASK	*AE*		*AF*		*AG*	
SRT	100.00	(.00)	100.00	(.00)	100.00	(.00)
2CH	89.86	(6.91)	91.45	(12.00)	94.07	(16.82)
CDS	87.06	(8.50)	86.92	(9.18)	93.80	(3.91)
CDI	65.63	(14.29)	73.36	(11.19)	88.13	(8.74)
CDD	61.33	(10.82)	68.44	(11.91)	84.17	(9.39)
CPT	73.03	(14.13)	77.06	(10.84)	86.88	(12.91)
DGS	68.70	(11.67)	72.02	(10.66)	76.39	(12.35)
MSP	64.79	(17.04)	80.33	(11.34)	85.78	(13.75)
SPD	75.63	(10.22)	81.00	(9.12)	90.67	(8.48)

Table 3-40. ANAMUKR: Efficiency (correct responses/min): 1997 means (and standard deviations) for the exposure groups.

TASK	*AE*		*AF*		*AG*	
SRT	94.69	(30.61)	103.23	(42.00)	133.87	(37.75)
2CH	67.28	(32.01)	75.70	(30.03)	91.45	(31.32)
CDS	23.89	(11.47)	20.03	(9.29)	30.44	(15.20)
CDI	19.28	(12.97)	21.26	(10.27)	27.19	(12.11)
CDD	18.55	(10.87)	25.00	(9.79)	27.13	(13.06)
CPT	54.01	(20.43)	58.27	(13.87)	71.16	(19.45)
DGS	23.00	(9.13)	26.12	(8.81)	25.80	(6.72)
MSP	18.43	(12.29)	24.09	(11.13)	27.04	(12.65)
SPD	20.66	(12.68)	20.16	(6.67)	24.63	(8.42)

Table 3-41. ANAMUKR: Additional measures: 1997 means (and standard deviations).

TASK	*AE*	*AF*	*AG*
TAP-R (mean n of responses in 10 sec)	42.97 (11.99)	51.20 (11.89)	57.47 (11.01)
TAP-L (mean n of responses in 10 sec)	37.81 (9.30)	46.16 (12.40)	51.43 (10.79)
SLP (scores from 1-7)	2.12 (.60)	1.87 (.64)	1.46 (.59)

3.7.3 GPAB.

From 1996 to 1997, Group ***AE*** declined on measures of explosive and dynamic strength, reflecting their continuing physical deterioration (see Table 3-42). Conversely, Groups ***AF*** and ***AG*** showed some improvement in physical abilities.

3.7.4 ANAMUKR: Accuracy.

As seen in Table 3-42, Group ***AE*** showed significant declines in accuracy from 1996 to 1997 on ***all*** tasks. This global decline in accuracy is most likely reflecting a general deterioration of their neurocognitive abilities; in fact, their levels of performance are similar to those observed in individuals with moderate-severe traumatic brain injuries (TBIs) (Levinson & Reeves, 1997; Levinson, et al, 1998). Similar declines were observed in Group ***AF***, on 6 of 8 tasks. Accuracy of performance of Group ***AG*** also declined on 3 tasks, although not as sharply as that of the other exposed groups.

3.7.5 ANAMUKR: Efficiency.

Group ***AE*** showed a significant decline in efficiency on **SRT** only, and when this was entered into a MANCOVA as a covariate, the multivariate difference in efficiency revealed by the MANOVA (see Table 3-37) was no longer significant. Group ***AF*** also showed a significant slowing of reaction time, and this most likely explains their corresponding decline in efficiency on **CPT**. Group ***AG*** did not exhibit any apparent slowing of reaction time, however, and therefore the significant declines on **CPT** and **DGS** are more likely reflecting difficulty in sustaining attention. At this point in time, the performance of all exposed groups on all tasks is significantly lower than that of the Controls.

Table 3-42. Significant declines in performance by the exposure groups: 1996 to 1997.

BATTERY: TASK	GROUP	F	*p*<	FIG. #
GPAB				
BROADJUMP	***AE***	7.87	.01	30
SQUATTHRUSTS	***AE***	3.49	.05*	32
ANAM-ACCURACY				
2CH	***AE***	14.59	.001	34
CDS	***AE, AF***	18.77, 11.88	.001, .001	35
CDI	***AE, AF***	23.02, 14.43	.001, .001	36
CDD	***AE, AF***	69.38, 14.21	.001, .001	37
CPT	***AE, AF, AG***	11.76, 18.07, 4.07	.001, .001, .05	38
DGS	***AE, AF, AG***	6.32, 16.09, 15.49	.01, .001, .001	39
MSP	***AE, AF, AG***	12.26, 9.29, 4.04	.001, .01, .05	40
SPD	***AE***	5.98	.05	41
ANAM-EFFICIENCY				
SRT	***AE, AF***	11.93, 7.24	.001, .01	42
CPT	***AF, AG***	5.56, 8.79	.05, .01	47
DGS	***AG***	13.89	.001	48

Note: *1-tailed

3.7.6 ANAMUKR*:* Additional Measures.

No significant declines in tapping rates for either hand were observed. Group ***AE*** showed a significant (.001) decrease in levels of sleepiness, while Group ***AF*** showed a significant increase.

3.8 RESULTS OF 1998 RETEST SESSION.

For similar reasons described for the 1997 retest, 1998 data were obtained on 22 Eliminators, 21 Forestry workers, and 29 Agricultural workers. Since some of these had not been available for testing on the GPAB and/or ANAMUKR in 1996, but were in 1997; therefore, the 1997-98 comparisons were based on Ns as follows: GPAB—Eliminators-22, Forestry workers-19, Agricultural workers-29; ANAMUKR—Eliminators-22, Forestry workers-20, Agricultural workers-29. Of the new group of 13 foresters from 1997, 8 were retested. Since this was only their second year of testing, their data were not included in the analyses.

3.8.1 Assessments of Declines by Exposure Groups.

Multivariate and univariate tests revealed no significant declines from 1997 levels on any measure in any of the test batteries, for any group. In fact, some of the groups showed significant increases in levels of performance compared to the 1995 control groups; these will be described in the relevant sections of this report.

3.8.2 GPAB.

Means and standard deviations on the 1998 retest are presented in Table 3-43. The ***AE***s showed significant increases in performance on **CARRYWGT**, **SQUATTHR** and **BALBEAM** (*ps* < .01), while the ***AG***s improved on **CARRYWGT** (.05).

Table 3-43. GPAB: 1998 means (and standard deviations) for the exposure groups.

TASK	***AE***		***AF***		***AG***	
BRODJMP (meter)	1.29	(.16)	1.42	(.24)	1.51	(.40)
CARRYWGT (meter)	31.82	(12.40)	41.62	(8.56)	44.58	(6.98)
SQUATTHR (number)	23.91	(7.51)	40.52	(12.02)	51.35	(19.01)
BALBEAM (meter)	17.36	(1.59)	19.93	(1.88)	19.96	(2.81)

3.8.3 ANAMUKR: Accuracy.

Means and standard deviations for the 1998 accuracy retest are presented in Table 3-44. Although some improvements over the 1997 levels were observed in some groups, none of these was significant.

Table 3-44. **ANAMUKR: Accuracy (% correct): 1998 means (and standard deviations for the Exposure Groups.**

TASK	*AE*		*AF*		*AG*	
SRT	100.00	(.00)	100.00	(.00)	100.00	(.00)
2CH	89.90	(5.56)	88.89	(10.25)	92.86	(14.32)
CDS	89.70	(6.62)	88.20	(2.75)	94.99	(3.72)
CDI	63.83	(8.99)	74.06	(11.52)	85.29	(10.92)
CDD	64.20	(11.92)	72.19	(10.23)	79.53	(13.56)
CPT	73.07	(16.74)	82.29	(9.35)	87.96	(11.58)
DGS	68.75	(10.11)	72.29	(9.59)	76.01	(13.94)
MSP	67.57	(16.75)	79.63	(8.39)	85.63	(17.57)
SPD	82.05	(10.98)	83.25	(5.45)	91.72	(5.39)

3.8.4 ANAMUKR: Efficiency.

Means and standard deviations in efficiency are presented in Table 3-45 compared to the 1995 control group. Significant (.05) increases in efficiency of performance were made by the ***AG***s on **SRT** and **SPD**. Although other increases in levels of performance were observed (see, e.g., Figures 3-43, 3-47, and 3-49), none were significant.

Table 3-45. ANAMUKR: Efficiency (correct responses/min) : 1998 means (and standard deviations) for the exposure groups.

TASK	*AE*	*AF*	*AG*
SRT	96.72 (38.46)	86.39 (20.87)	150.20 (31.82)
2CH	60.31 (30.64)	63.69 (22.84)	100.70 (26.94)
CDS	18.62 (7.61)	21.56 (13.28)	33.82 (11.59)
CDI	15.97 (9.63)	18.32 (13.11)	28.06 (12.38)
CDD	14.25 (6.10)	16.58 (8.19)	29.02 (10.22)
CPT	53.60 (16.77)	63.26 (13.80)	76.97 (15.54)
DGS	19.64 (5.66)	22.73 (8.38)	27.36 (7.04)
MSP	15.38 (9.89)	19.32 (13.10)	30.10 (13.31)
SPD	16.32 (9.07)	19.45 (9.27)	28.15 (6.85)

3.8.5 ANAMUKR*:* Additional measures.

Means and standard deviations for these are presented in Table 3-46. Group *AG* showed a significant increase (.05) in **TAP-L**.

Table 3-46. ANAMUKR: Additional Measures: 1998 Means (and Standard Deviations).

TASK	*AE*	*AF*	*AG*
TAP-R (mean n of responses in 10 sec)	47.64 (6.48)	49.65 (6.09)	59.48 (10.29)
TAP-L (mean n of responses in 10 sec)	40.80 (5.36)	43.53 (6.62)	53.84 (10.14)
SLP (scores from 1-7)	2.32 (.72)	1.70 (.66)	1.21 (.49)

Figures 3-30 through 3-53 graphically illustrate yearly changes in performance from 1995-1998 on all measures. The 4-year averaged levels of the Controls are represented as a straight dotted line (typically across the top) on each figure. Each graph represents the mean and the standard deviation are identified in their appropriate tables.

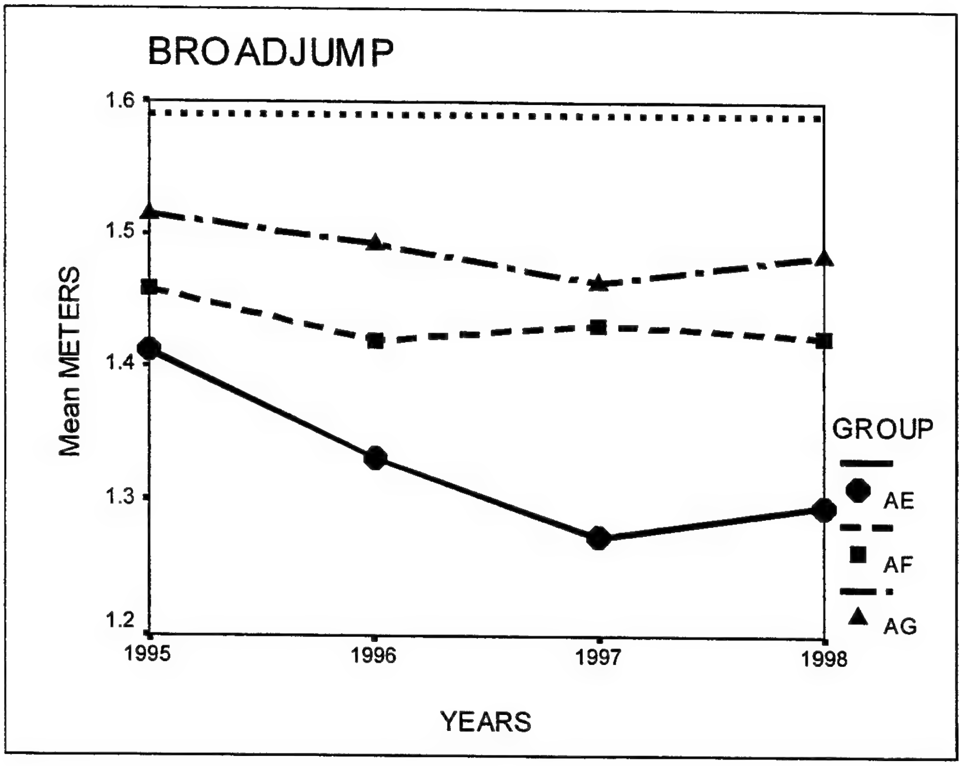

Figure 3-30. Mean performance on GPAB: BROADJUMP.

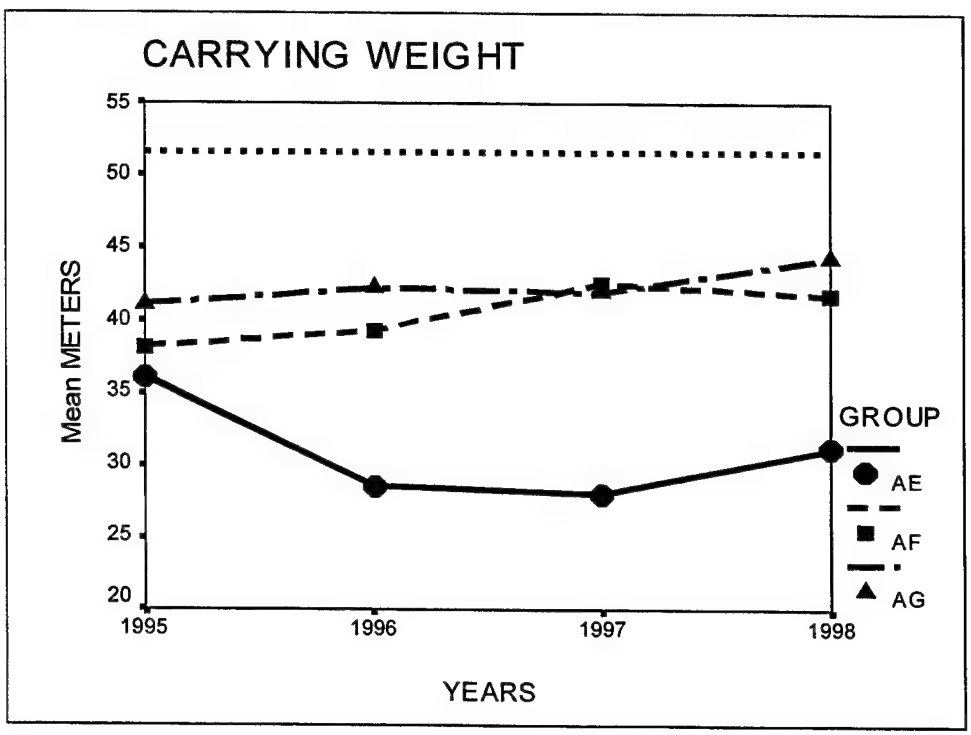

Figure 3-31. Mean performance on GPAB: CARRYING WEIGHT.

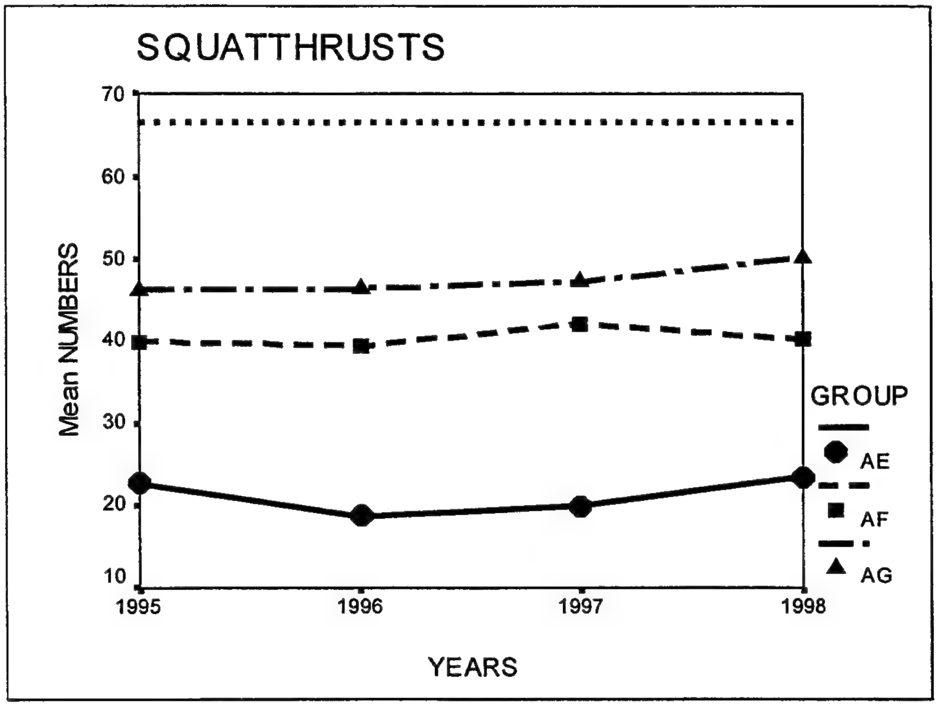

Figure 3-32. Mean performance on GPAB: SQUAT THRUSTS.

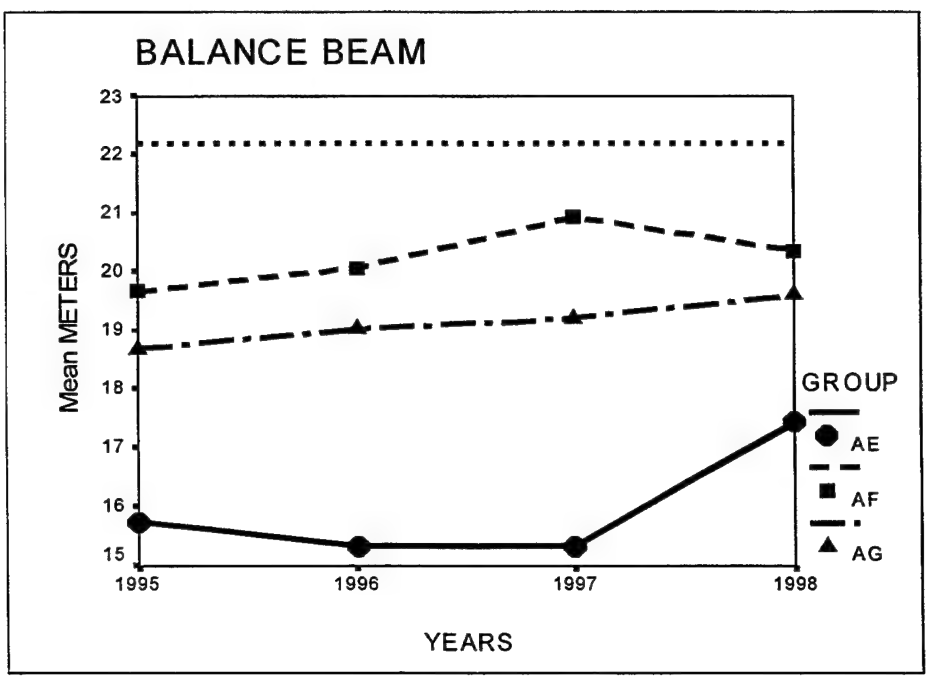

Figure 3-33. Mean performance on GPAB: BALANCE BEAM.

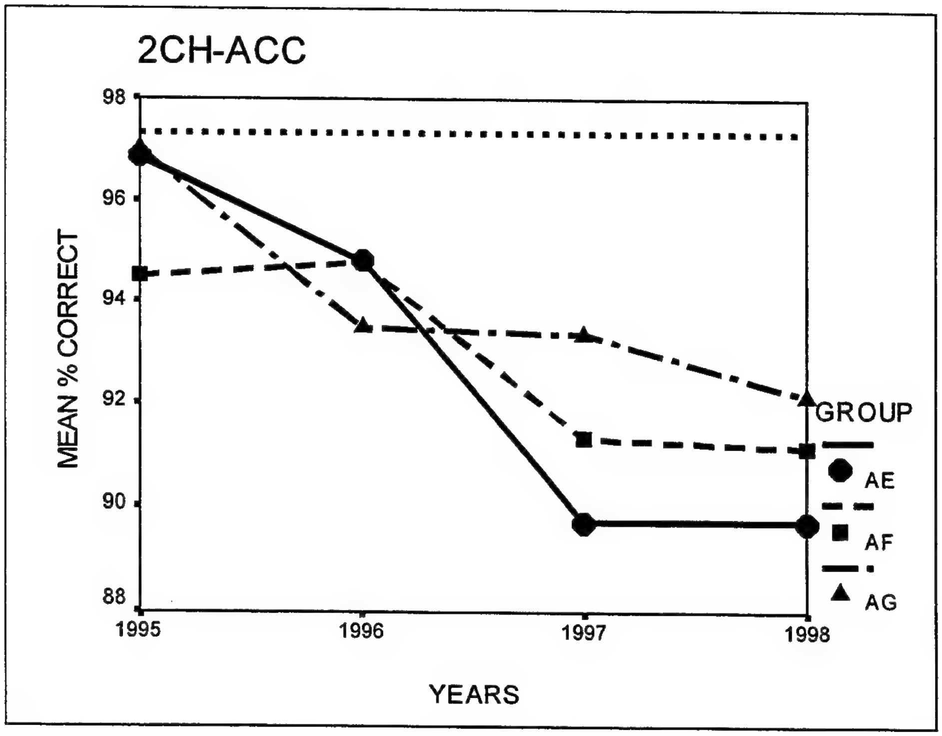

Figure 3-34. Mean performance on ANAMUKR: 2CH-ACC.

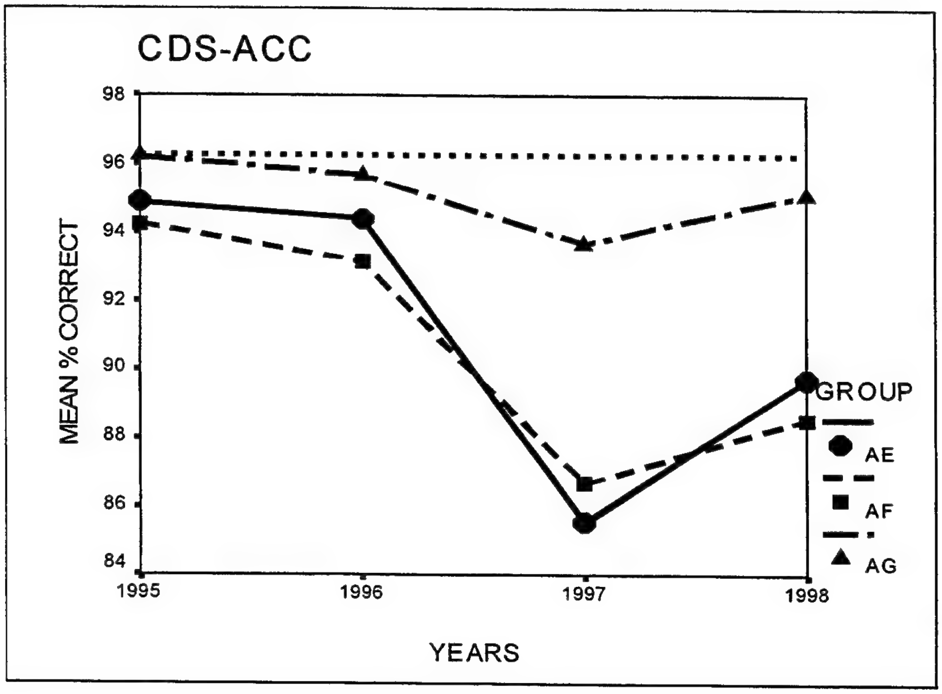

Figure 3-35. Mean performance on ANAMUKR: CDS-ACC.

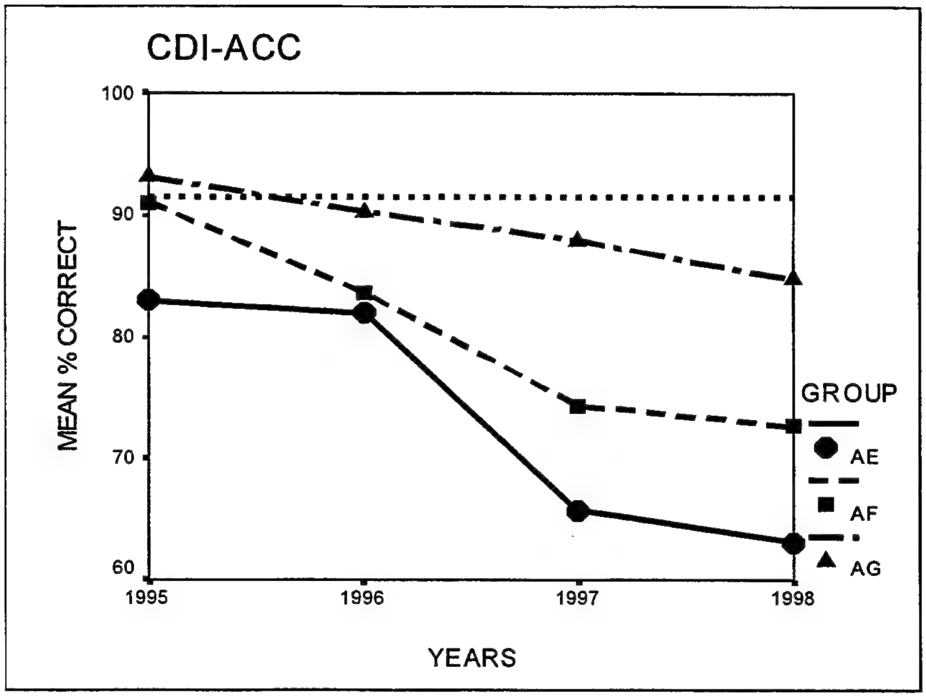

Figure 3-36. Mean performance on ANAMUKR: CDI-ACC.

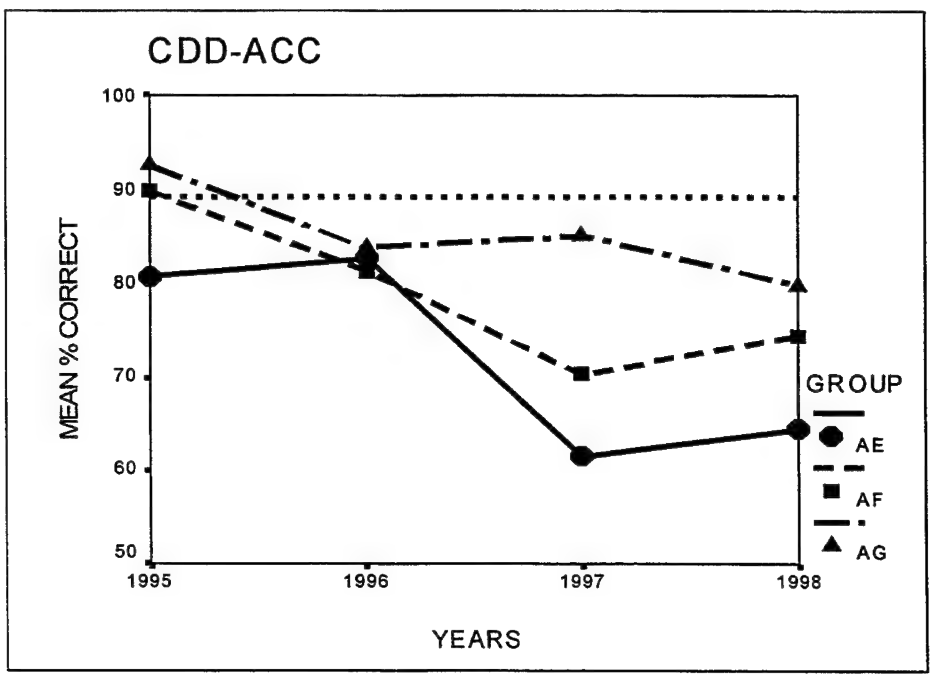

Figure 3-37. Mean performance on ANAMUKR: CDD-ACC.

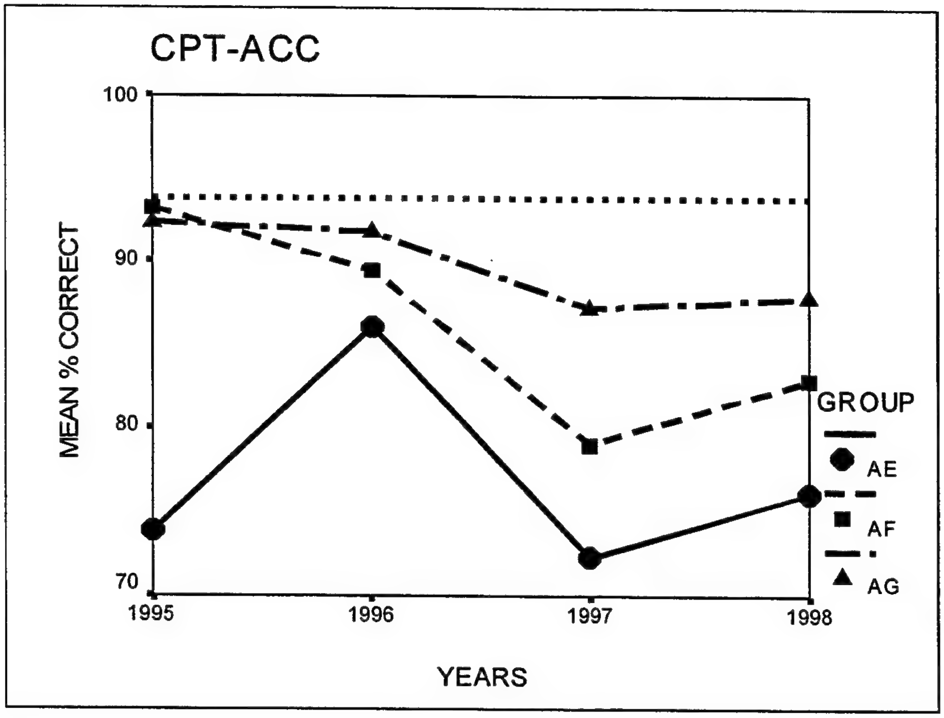

Figure 3-38. Mean performance on ANAMUKR: CPT-ACC.

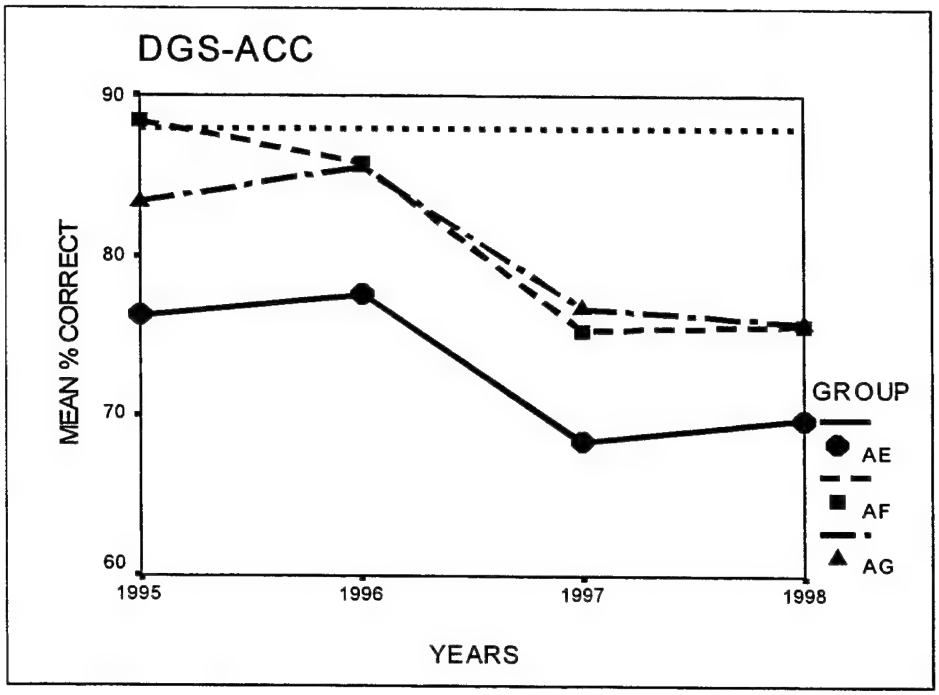

Figure 3-39. Mean performance on ANAMUKR: DGS-ACC.

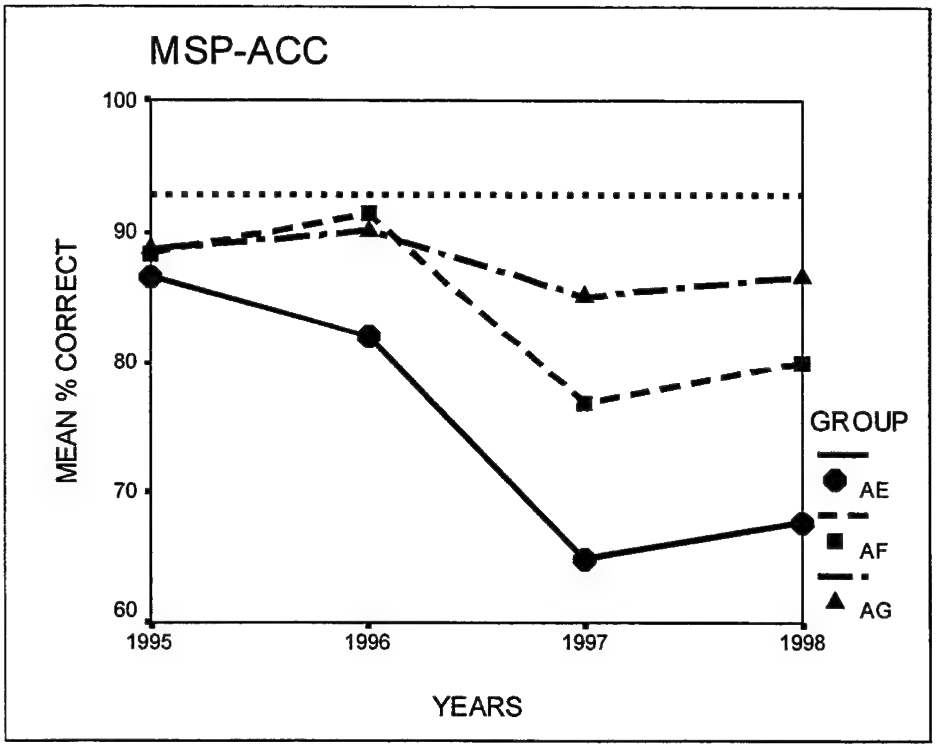

Figure 3-40. Mean performance on ANAMUKR: MSP-ACC.

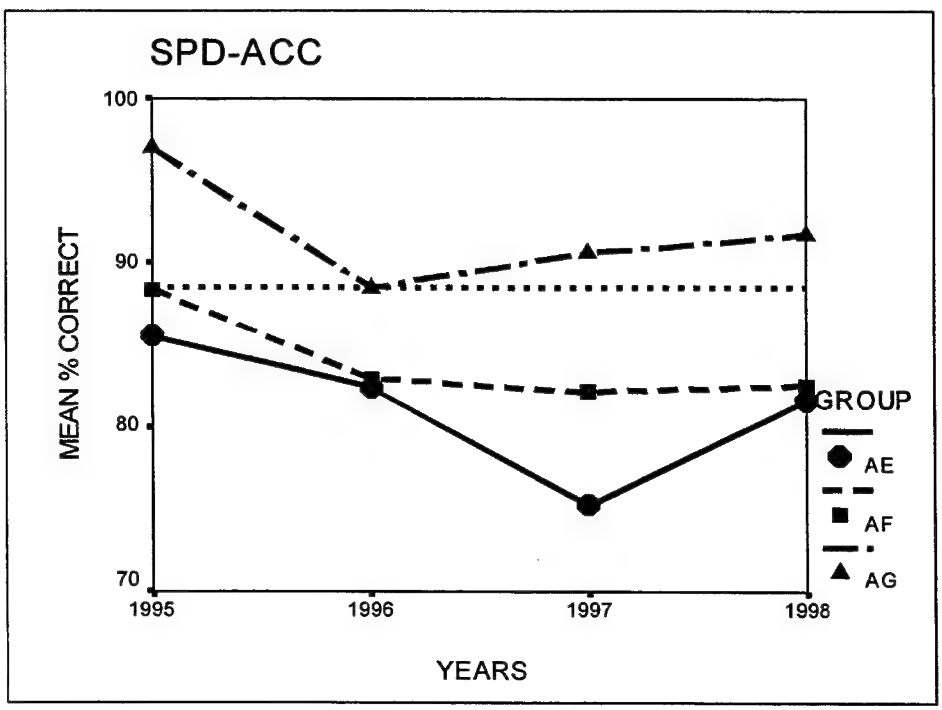

Figure 3- 41. Mean performance on ANAMUKR: SPD-ACC.

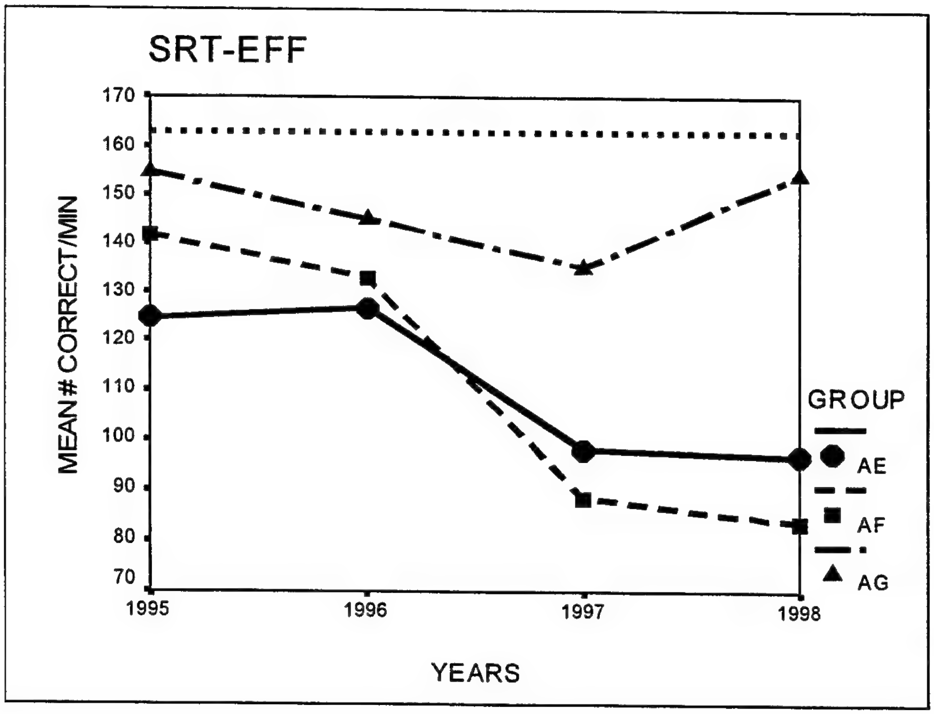

Figure 3-42. Mean performance on ANAMUKR: SRT-EFF.

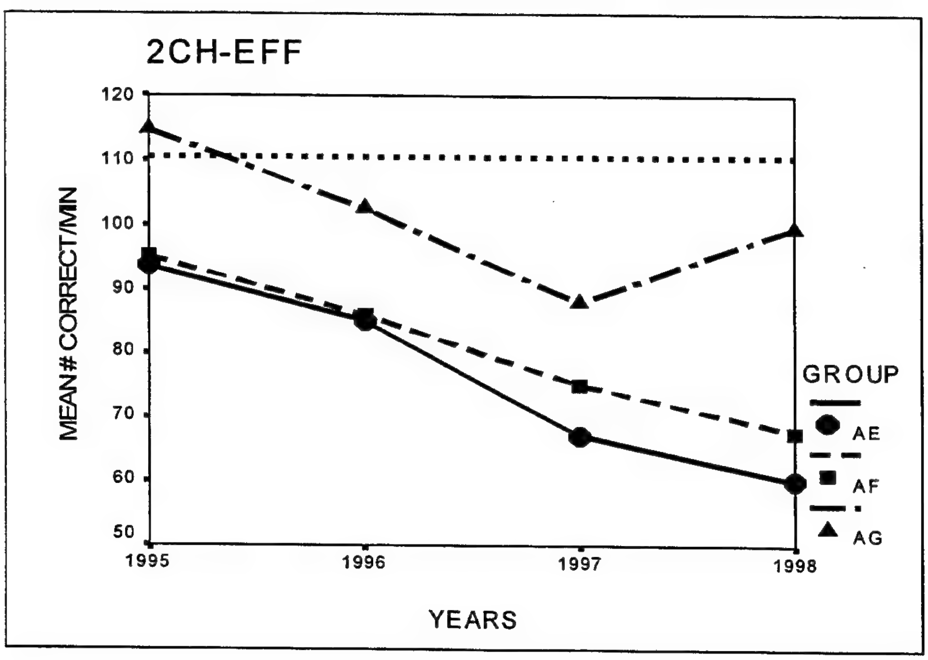

Figure 3-43. Mean performance on ANAMUKR: 2CH-EFF.

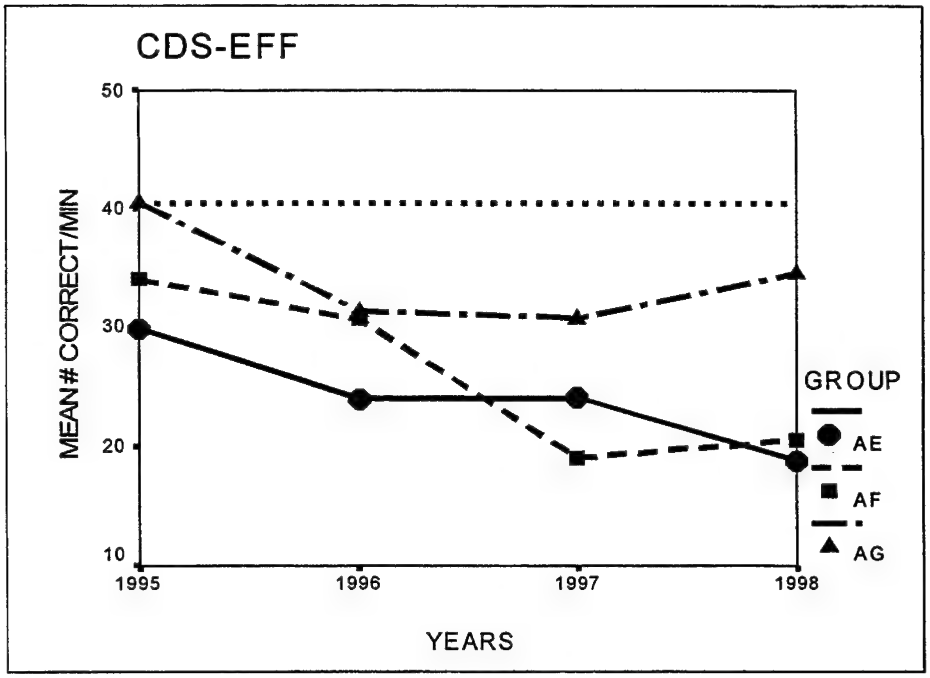

Figure 3-44. Mean performance on ANAMUKR: CDS-EFF.

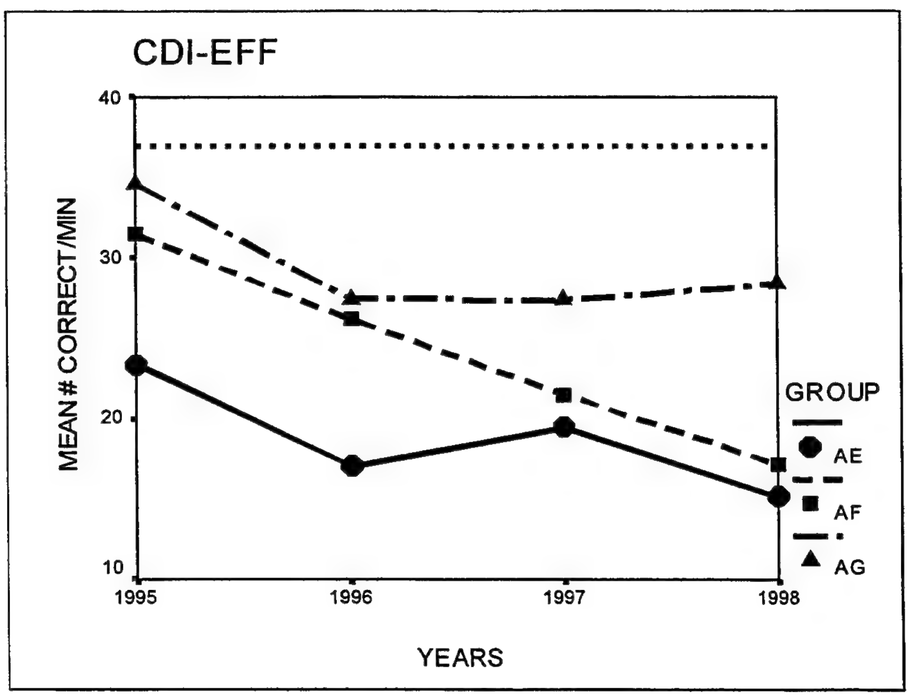

Figure 3-45. Mean performance on ANAMUKR: CDI-EFF.

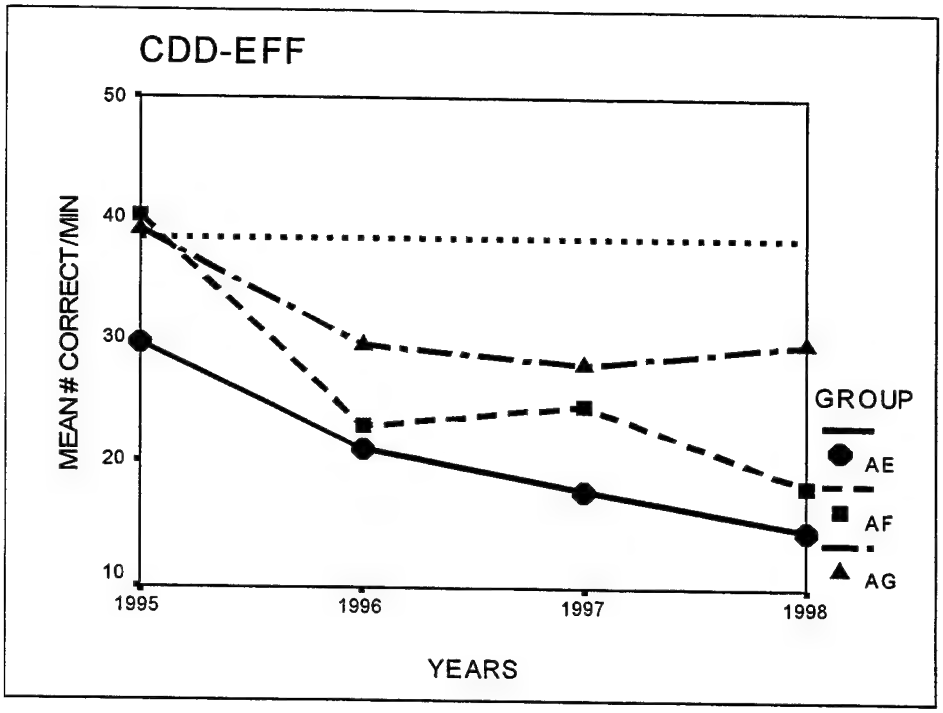

Figure 3-46. Mean performance on ANAMUKR: CDD-EFF.

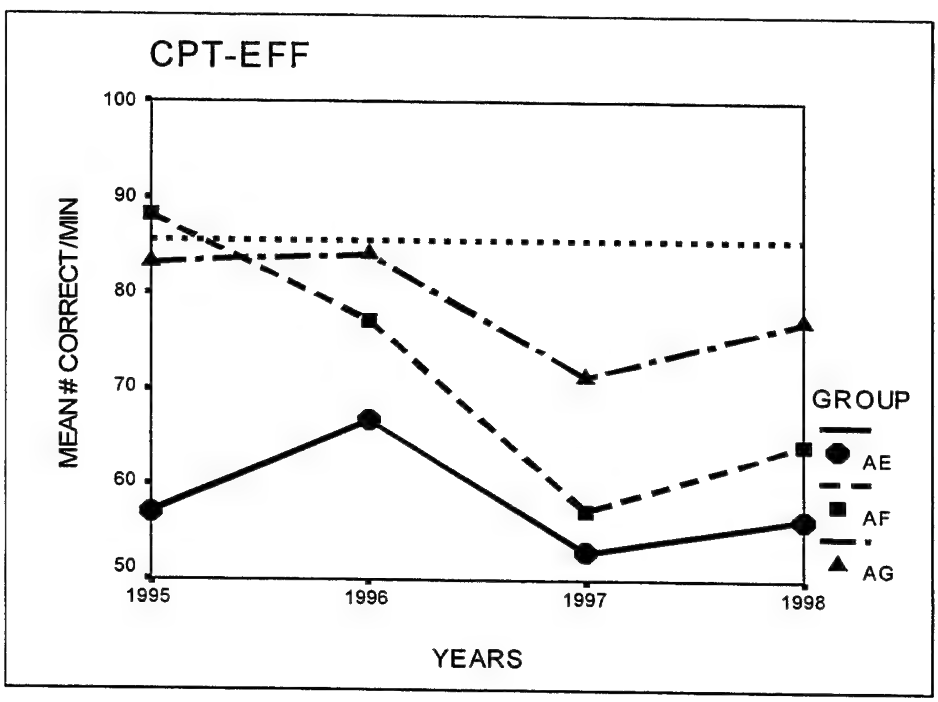

Figure 3-47. Mean performance on ANAMUKR: CPT-EFF.

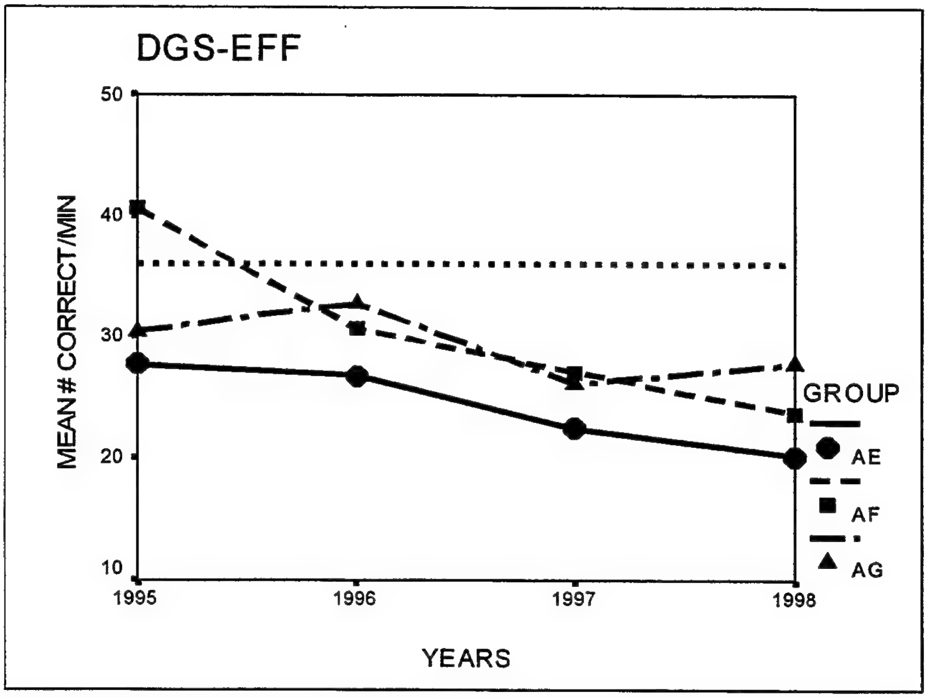

Figure 3-48. Mean performance on ANAMUKR: DGS-EFF.

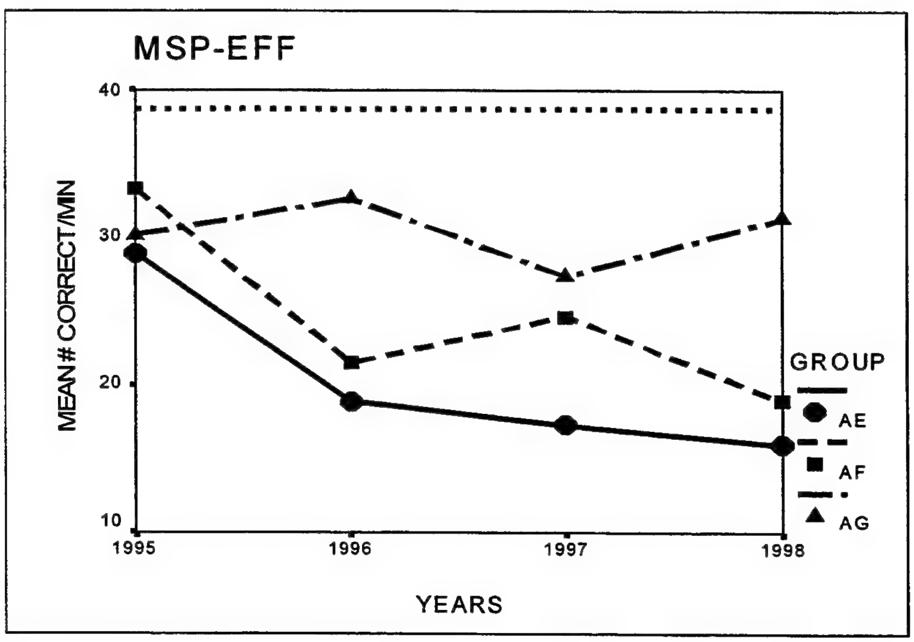

Figure 3-49. Mean performance on ANAMUKR: MSP-EFF.

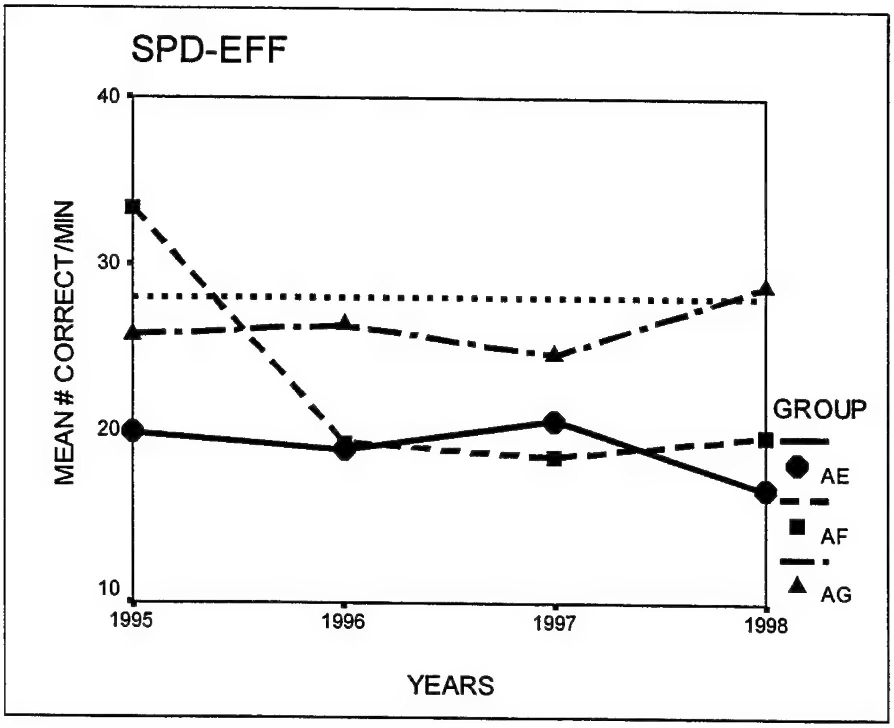

Figure 3-50. Mean performance on ANAMUKR: SPD-EFF.

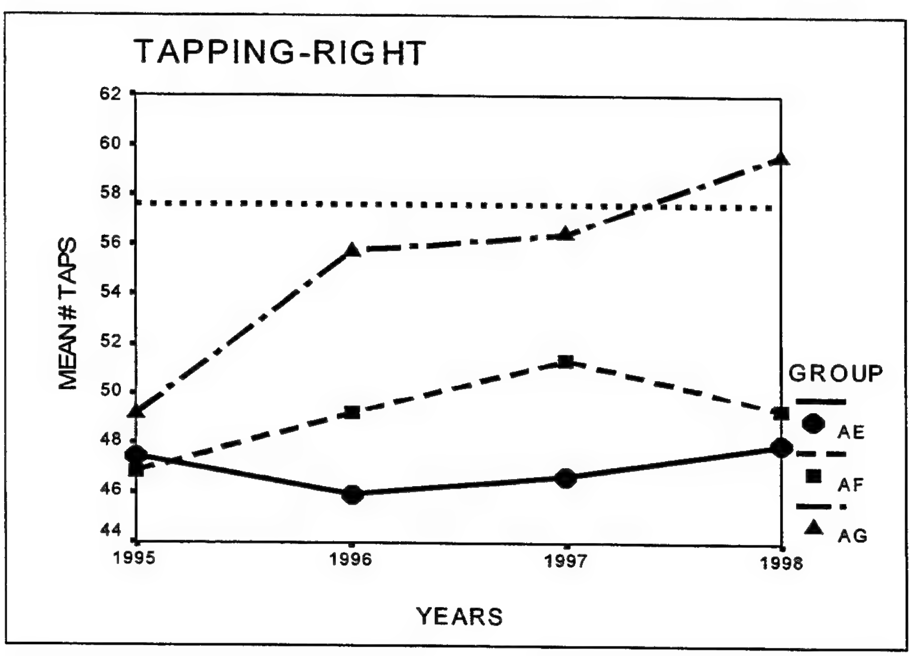

Figure 3-51. Mean performance on ANAMUKR: TAPPING-RIGHT.

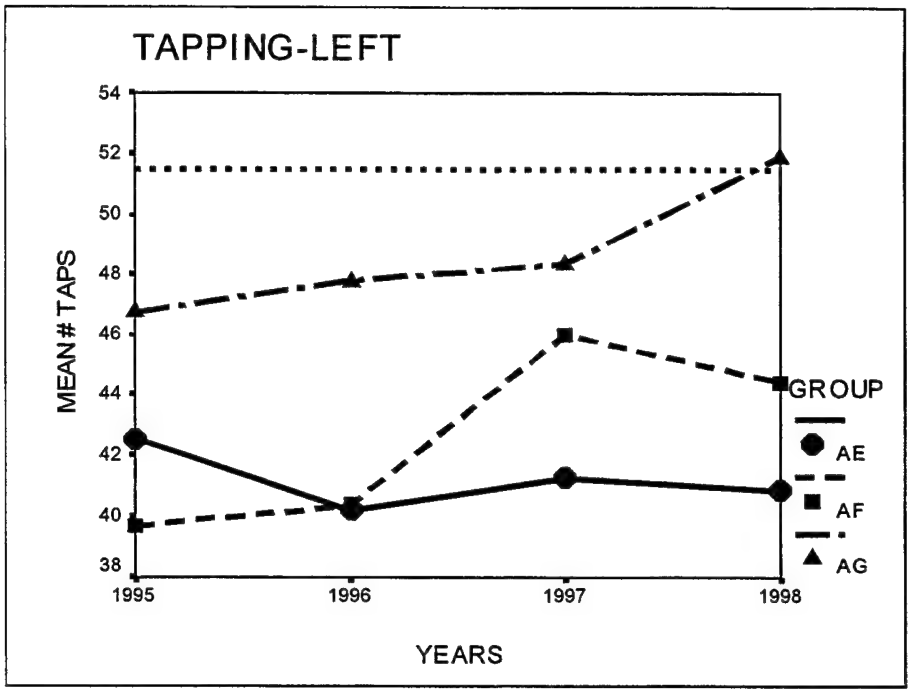

Figure 3-52. Mean performance on ANAMUKR: TAPPING-LEFT.

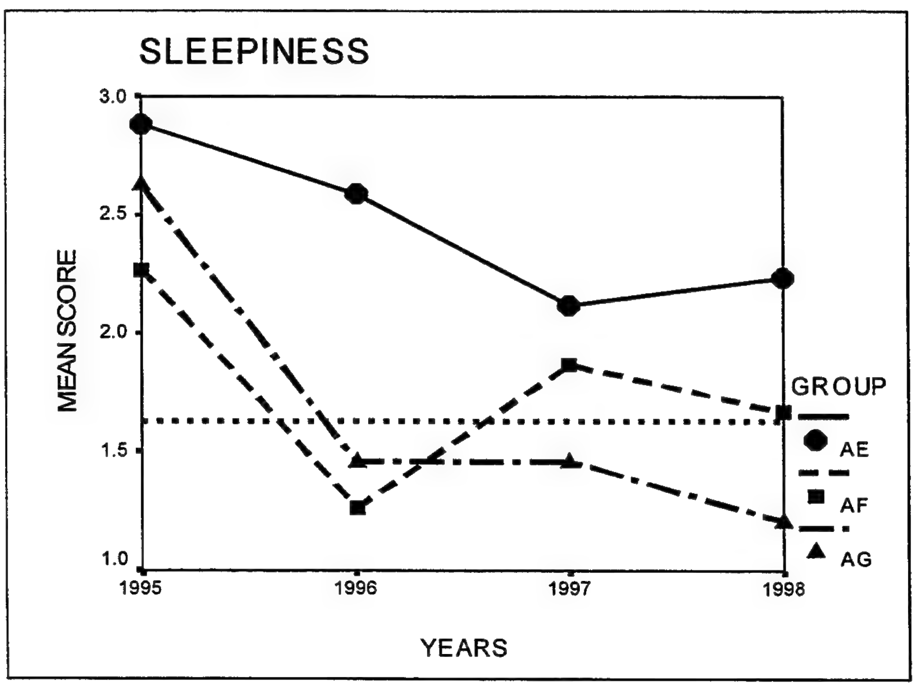

Figure 3-53. Mean ratings on ANAMUKR: SLEEP SCALE.

SECTION 4
CONCLUSIONS

Taken collectively, the results of the data analyses are rather frightening. Initial dosages were from 1 rad to 183 rads. Our research suggests neurocognitive and physical decrements in performance 12 years AFTER a nuclear accident. They indicate that not only have cognitive and physical functioning of the ***AE***s been severely compromised by exposure to the environmental effects of the ionizing radiation being emitted by the Chernobyl power station, but also that cognitive and physical performance of the other groups (***AF***s, ***AG***s) in the vicinity of Chernobyl have been affected as well, although to a lesser degree. At this point it is hard to specify whether the observed impairments are permanent or temporary (although they would appear to be permanent in the ***AE***s). It is also difficult to determine whether they are a result of direct effects of radiation on the CNS itself, as opposed to being an indirect result of bodily illness resulting from chronic radiation perhaps paralleling that experienced by people diagnosed as suffering from reporting heat exhaustion (Gestaldo, et. al., 1997). It is also possible that the individuals in and around the Chernobyl area are experiencing symptoms somehow similar to those of the "neurasthenic syndrome," which was reported by Soviet workers exposed to non-ionizing microwave radiation in the 1980's. As described by Akoyev and Justesen (personal communication), this syndrome included fatigue, malaise, and achiness. Such factors would most certainly result in compromised performance on neurocognitive tasks requiring attention and working memory, and on physical tasks requiring explosive and sustained energy. Since this study was not a "medical" study, we were not equipped to identify aplastic anemia (pancytopenia).

The results of the 1996 retest indicated that both the physical and cognitive abilities of the individuals initially exposed (Eliminators) to the ionizing radiation resulting from the Chernobyl nuclear accident were seriously declining. Although the 1997 retest indicated that the forestry and agricultural workers were actually improving on the physical tasks, the cognitive performance of these groups was becoming globally impaired; i.e., they showed significant impairments on the majority of the ANAMUKR tasks. This global impairment is reminiscent of that observed in survivors of moderate-to-severe traumatic brain injuries (Levinson & Reeves, 1997; Levinson, et al, 1998). Unlike those people, however, whose cognitive performance improved over time, these individuals continued to experience increasing difficulty in neurocognitive function. As of eleven years after the accident, they continued to decline and had not yet plateaued. The results of the 1998 retest indicate that the declines of the exposure groups appeared to be leveling off, and improvements in performance were observed in some cases. Nevertheless, the results of analyses of the 4-year averaged scores indicate that the effects of exposure to radionuclides in and around the area of Chernobyl have resulted in clinically meaningful impairments in both physical and cognitive performance. Further, the finding that significant correlations between dosage and 4-year averaged performance occurred on ***21*** of 24 tasks for the combined exposure groups is extremely disconcerting. Retests performed during the next several years will be extremely valuable in determining whether the physical and neurocognitive performance of these individuals resumes to decline, continues to plateau, or begins to improve.

There are in the literature, several views on low-dosage radiation. One view holds that low-dosage does not cause an increase in cancer. However, our end was "performance" and physical and neuropsychological performance, according to our study, has been severely compromised. We believe it is time to take into account performance as well as health consequences.

Ukrainians have suffered serious medical problems as a result of the Chernobyl disaster, and their country has suffered economically since the accident. The burden of medical treatment is enormous and containment of nuclear pollution is almost impossible. Ukrainian scholars and scientists are generally in agreement that Chernobyl was one of the causes for Ukrainian independence from the former Soviet Union. For Russia the economic expenditures for environmental clean-up and treatment of the population were prohibitive.

In 1991, the Ukrainian Supreme Soviet enacted a law, which would decommission Chernobyl by the end of 1993; however, in October 1993, this law was repealed. The cost of decommissioning Chernobyl, especially in light of obtaining alternate energy sources, remains too great. The Chairman of the Ukrainian Supreme Soviet Committee on Chernobyl, Volodymyr Javorivsky said, "We will be extracting problems from the well of Chernobyl for a very long time." In light of this report, that is an understatement.

To put this report into some perspective it needs to be stated that while contamination of the eco-structure is considerable, much of the contamination affecting the Ukraine is below international standards for life-time dosages. Poor diet, the stress of living in a country where the minimum wage is $1.50 per month, and where food is a daily preoccupation, are not adequately addressed in medical reports which blame Chernobyl for all increases in disease. Yet research has shown that exposure to ionizing radiation is harmful to humans and the environment. The effects of living in contaminated areas, as well as growing and consuming contaminated food, have received little research support. The psychological concomitants of Post-Traumatic Stress Disorder are being considered in terms of recent child development studies in the Ukraine.

The Ukrainians are desirous for research support. The Ministry of Forests is particularly interested in research support to develop models for cognitive and physical decrements in performance associated with forestry workers exposed to contaminated forests. The Director of the Ukrainian Psychological Research Institute is also desirous of research support dealing with psycho-sociological problems associated with adults and children living in contaminated areas, or who have relocated from these areas. The need for assistance to help plan and guide longitudinal research has been expressed by those who have been working with the children affected by the Chernobyl disaster.

The benefits of these research proposals would be enormous for the United States. Nuclear energy is a fact worldwide. Data gathered by research efforts involving Chernobyl could impact Federal Emergency Management Administration procedures for relocating victims of similar accidents, and their medical and psychological treatment. Unfortunately, in the conduct of this research, a wealth of data was obtained that is available, however, funds were not allocated for analyses. In addition, little is known about cognitive and physical decrements in performance or stress associated with living and working in contaminated areas. Preparedness should be the bottom line in research.

Read (1993) mentions that because radiation technology was so new, there was no way to be prepared for all possible problems resulting from its use. Nonetheless, it is important that people learn from such accidents about the effects of radiation, especially considering the aftermath of nuclear war or terrorist attack. This remains one of the objectives of the present, ongoing study of the physical and neurocognitive effects of the Chernobyl accident.

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APPENDIX A
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Child Psychologist, Natalia A. Bastun
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APPENDIX B
PHOTOGRAPHS OF CHERNOBYL
AND
TESTING SITES

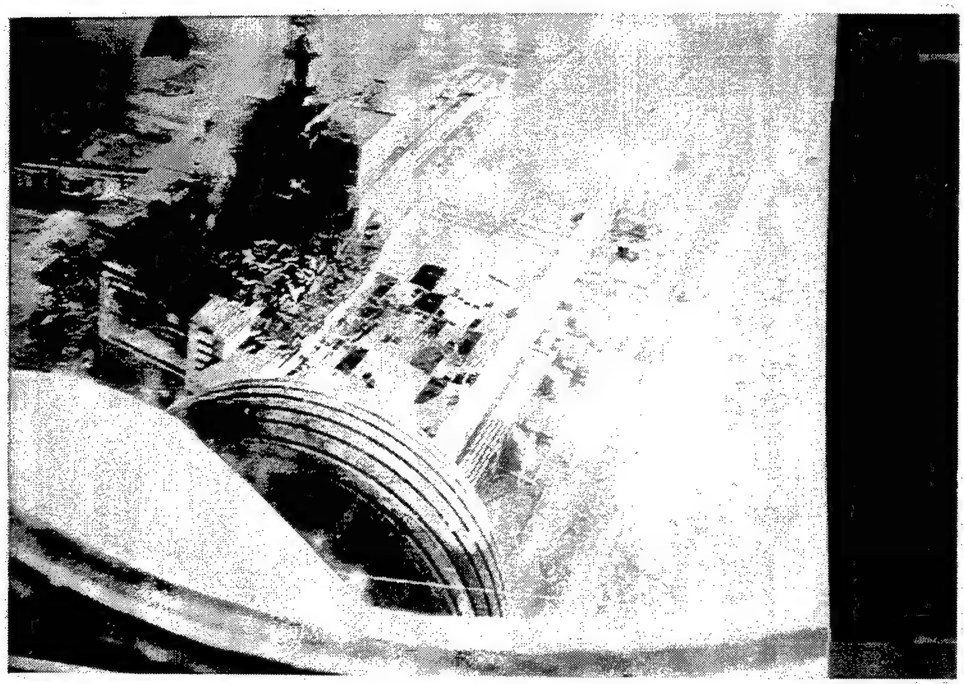

Figure B-1. Chernobyl site after explosion, 26 April 1986.

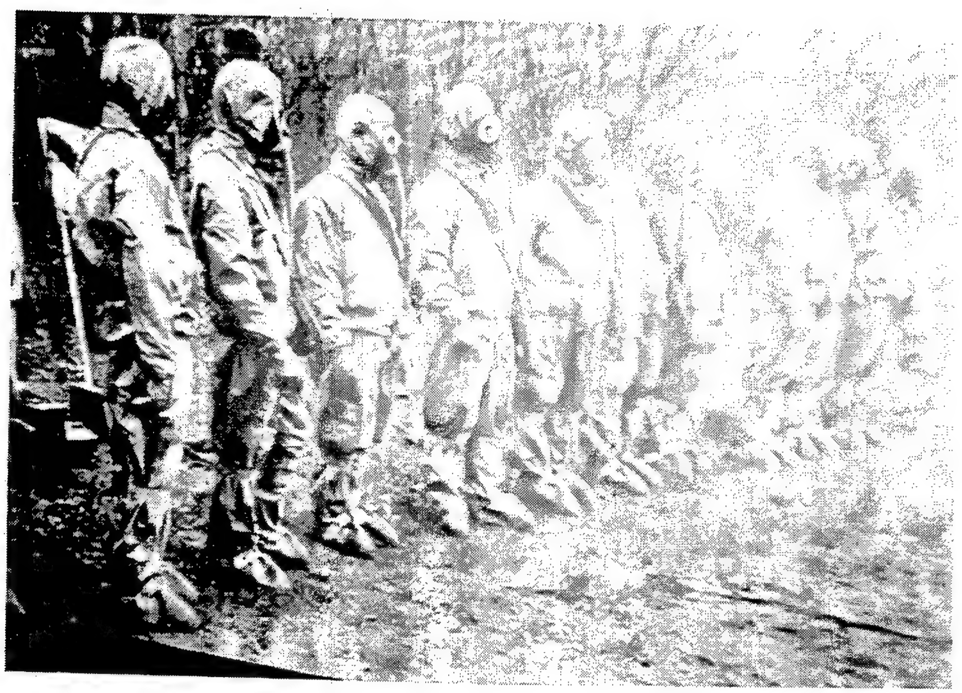

Figure B-2. Russian monitors, 26 April 1986.

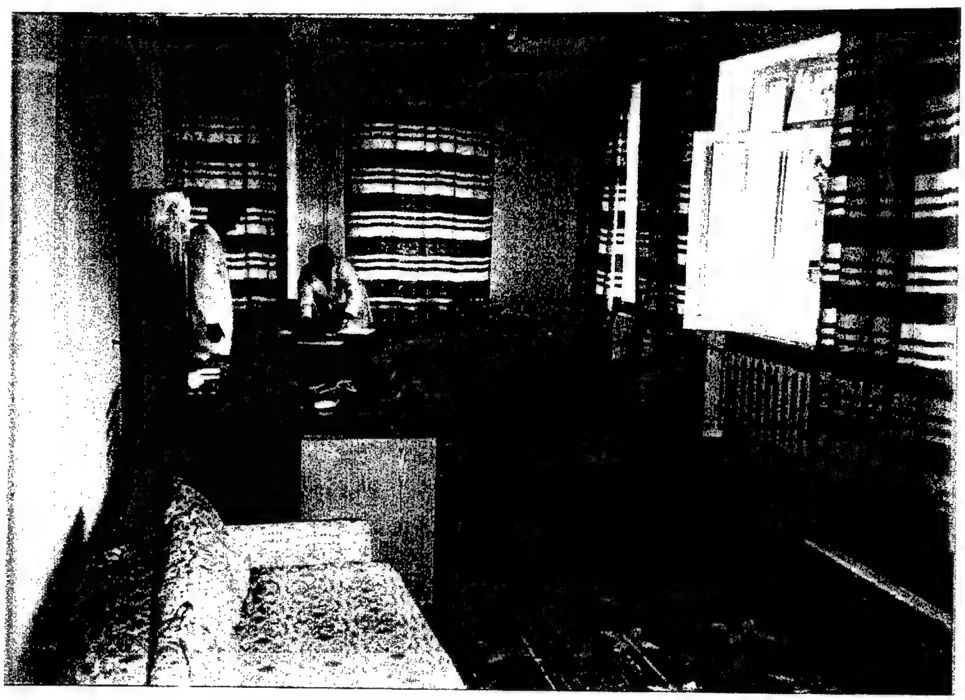

Figure B–3. Setting up to test eliminators.

Figure B-4. Agricultural workers ready for testing on ANAMUKR.

Figure B-5. Agricultural workers walking on balance beam.

Figure B-6. Agricultural workers performing broad jump.

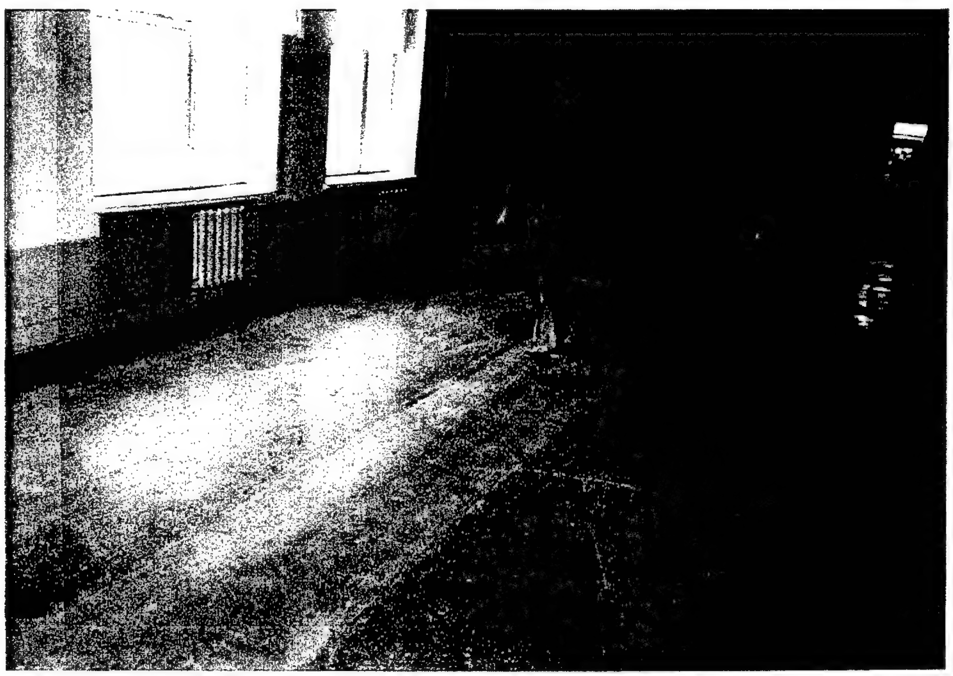

Figure B-7. Control person carrying weights.

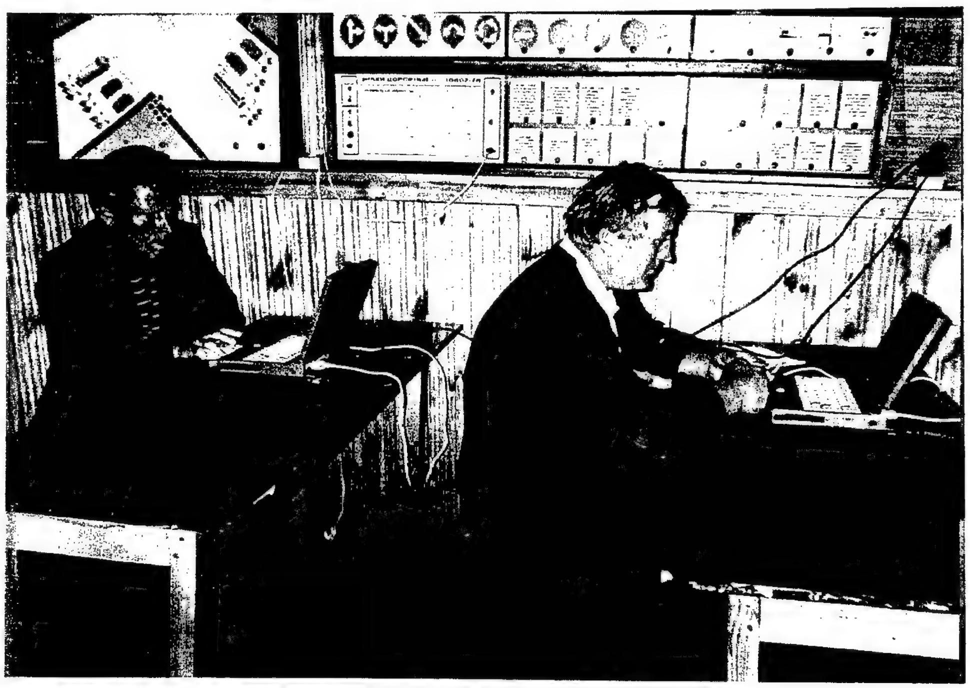

Figure B-8. Forestry workers performing ANAM.

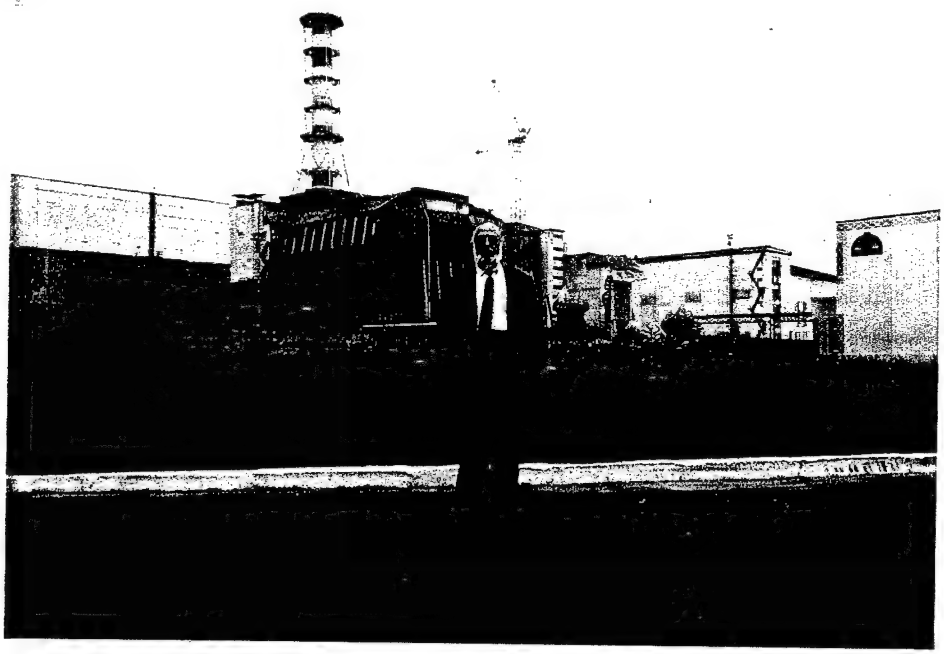

Figure B-9. Dr. Gamache at Chernobyl Nuclear Power Plant, 1997.

APPENDIX C
CONSENT FORM

Dear____

You are invited to participate as a VOLUNTEER in a 4-year MINIMAL RISK research project designed to test your physical and cognitive performance. This research is conducted by KGA International, Kiev Polytechnic Institute, and the Ukraine Center for Radiation Medicine. The research is planned for 1995-1998, and the testing will be carried out in the summer months and will require you to be tested, as scheduled. Complete testing will take one-half day.

Prior to testing you will be provided with instructions how to perform the tests. The physical part of testing is based on simple exercises that are easy to perform for any individual. The cognitive test will be performed on a computer with appropriate instructions in Russian.

If, during the testing, you feel ill or want to ask a question, notify your instructor immediately. If you are ill, the instructor will refer you to the medical staff. Inquries regarding instructions given MAY necessitate starting testing over again. Make sure to ask ALL questions prior to commencing the test procedure.

I, certify that I am a volunteer and all procedures and risks have been thoroughly explained to me. I also have the choice NOT to participate at any time.

Signature______________________________________
Date_______________

APPENDIX D
GLOSSARY

2CH	Two-choice Reaction Time
AC	Control group
ACC	Accuracy
AE	Eliminator group
AF	Forester group
AG	Agricultural group
ANAM	Automated Neuropsychological Assessment Matrices
ANAM-ACC	ANAMUKR – accuracy scores
ANAM-EFF	ANAMUKR – efficiency sores
ANAMUKR	Special subset of ANAM created for this study
BALBEAM	Balance Beam
BROADJMP	Broad jump
CARRYWGT	Carrying weights
CDD	Code Substitution – delayed recall
CDI	Code Substitution – immediate recall
CDS	Code Substitution – visual search
COMP	Composite measure
CPT	Running Memory Continuous Performance Task
DECL	Decline
DECR	Decrement
DGS	Digit Symbol
EFF	Efficiency
GPAB	Gamache Physical Abilities Battery
MSP	Matching to Sample
SLP	Stanford Sleepiness Scale
SPD	Spatial Processing
SQUATTHR	Squat thrusts
SRT	Simple Reaction Time
TAP-L	Tapping – left index finger
TAP-R	Tapping – right index finger

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